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TEKOA WASTEWATER TREATMENT PLANT LIMITED CLASS II AND RECEIVING WATER SURVEY

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ABSTRACT

Ecology's Surface Water Investigations Section conducted a limited Class II survey and receiving water study of the Tekoa Wastewater Treatment Plant (WTP) and Hangman Creek on August 30-31, 1988. Streamflow during the study was estimated to be about 63 percent of the 7-day, 10-year (7Q10) low flow. Biological oxygen demand (BOD) and total suspended solids (TSS) removal were within permit limits. Disturbance of the solids accumulated in the chlorine contact chamber during recent cleaning resulted in poor disinfection and violations of fecal coliform discharge limits. Degraded conditions in Hangman Creek resulted from lack of effluent dilution (1.6:1, receiving water: effluent) as well as agricultural nonpoint sources. Conditions showing deterioration below the WTP included: dissolved oxygen and macroinvertebrate viability, as well as nutrient and fecal coliform loading. A total maximum daily load analysis indicated extreme chlorine toxicity at dilution ratios less than 45:1. Temperature, dissolved oxygen, nutrient and bacteria loading calculations also indicate water quality violations at 7Q10 flows. Recommendations include installation of a chlorine removal system and effluent removal from the creek when dilution is less than 10:1.

PROJECT PURPOSE

Modifications to improve Tekoa WTP performance are currently being designed. Construction of these modifications is expected to follow soon. Receiving water effects from the WTP have not been previously assessed. Carl Nuechterlein of Ecology's Eastern Regional Office (ERO) requested that a limited Class II inspection and receiving water study be conducted to aid in designing plan modifications.

The objectives of this investigation were to determine the effects of the WTP discharge on Hangman Creek under summer low-flow conditions and to assess treatment plant efficiency.

BACKGROUND

The Tekoa WTP located about 40 miles southeast of Spokane serves roughly 850 people. The plant discharges into upper Hangman Creek. A previous field study of treatment efficiency conducted during winter (Yake, 1979) did not assess effluent impacts on the receiving water.

Upper Hangman (Latah) Creek is a small, slow-moving creek southeast of Spokane (Figure 1). Little Hangman Creek flows into Hangman Creek about 0.4 mile upstream of the Tekoa discharge. Intensive wheat production occupies most of the watershed, although cattle pastures occupy most of the immediate study area. Both wheat and cattle production contribute to deteriorated stream conditions. Inadequate vegetation along the creek allows severe bank erosion from wheat field runoff. Cattle access to the creek likewise increases erosion and water quality degradation. The creek is designated Class A (Excellent) under Chapter 173-201 of the Washington Administrative Code (WAC).

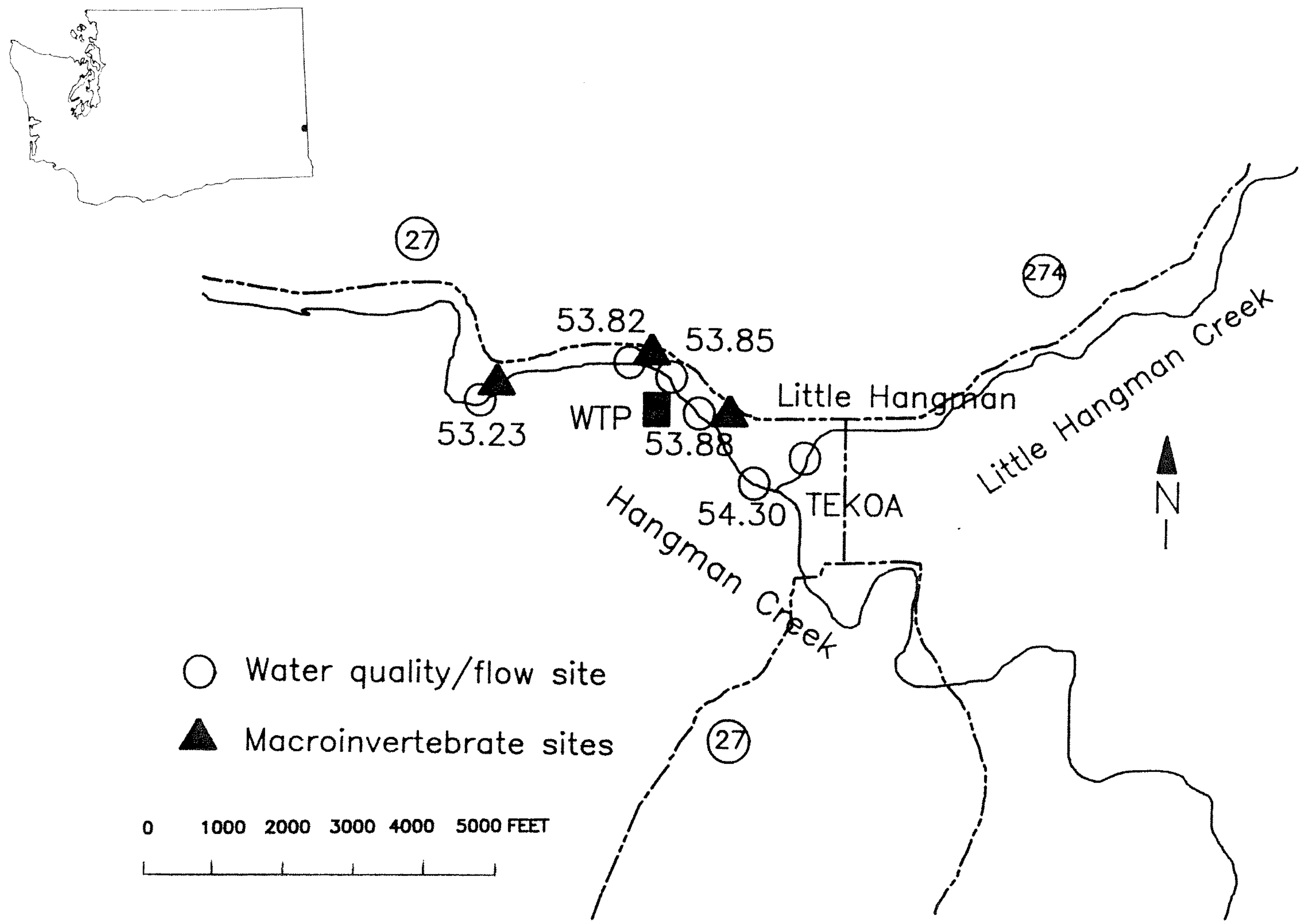

Figure 1. Map of study area and receiving water sampling sites for the Tekoa WTP limited Class II survey on August 30-31, 1988. Site numbers represent river miles.

The Tekoa WTP discharge to upper Hangman Creek is regulated under NPDES (National Pollutant Discharge Elimination System) Permit WA 002314-1, issued December 22, 1988. Table 1 shows the permit requirements for discharge quality.

Since the plant was upgraded in 1975, a modified activated sludge process has provided secondary treatment at the Tekoa WTP. Between 1950 and 1975, a trickling filter system provided primary treatment at the plant. An unusual feature of the upgraded plant design is a modified circular clarifier which serves as the chlorine contact chamber.

Inspections at the Tekoa WTP have indicated good treatment (Yake, 1979; Tom, 1987), although excessive infiltration and inflow (I/I) have been a chronic problem (Nuechterlein, 1988). Some of the I/I problems were corrected following a 1983 order by Ecology. Additional concerns about the treatment plant as well as remaining I/I concerns lead to a complete sewer system evaluation in 1986. Options considered for the plant ranged from wastewater treatment system replacement to modifications that would improve current operations. Since the cost for replacement of the WTP and removal of the discharge from the creek far exceeded the funds available, upgrade of the current plant was the alternative chosen. A Centennial Clean Water grant was awarded to the city of Tekoa in 1988 to design and construct the modifications. Included in the modifications will be a new headworks, pump station, flow measuring system, and sludge handling equipment.

The objectives of the 1988 study were to:

1. Determine effects of the current discharge on water quality in Hangman Creek under summer low-flow conditions.

2. Evaluate WTP removal efficiency and permit compliance.

3. Evaluate dry weather effluent loading characteristics at the Tekoa WTP.

Drought conditions were declared in most parts of eastern Washington during the summer of 1988. Only a trace of rain was reported during August at the Spokane Airport on August 16 and 20. Total precipitation for August was 0.74 inches below normal. Precipitation in June and July were slightly below normal. Similar lack of rain was reported at two towns near Tekoa: Rosalia and St. John (NOAA, 1988). River flows were at or below 7Q10 flows in most of eastern Washington.

METHODS

Composite and grab samples were collected at the Tekoa WTP influent and effluent on August 30-31, 1988. Influent samples were collected at the comminutor (Figure 2). Influent enters a wet well and is pumped intermittently to the comminutor when material in the well reaches a sufficient height. Effluent samples were collected at the end of the chlorine contact chamber below the V-notch weir. Composite samples collected by EILS (Environmental Investigations and Laboratory Services) and the WTP operator were split to compare BOD_5 and TSS results.

Table 1. Tekoa wastewater treatment plant NPDES permit limits and sampling schedule. The permit #002314-1 expires December 22, 1993.

SPECIAL CONDITIONS

S1. EFFLUENT LIMITATIONS

After issuance date, the permittee is authorized to discharge subject to meeting the following limitations for secondary treatment:

The monthly average dry weather quantity of effluent discharge shall not exceed 0.20 mgd. The monthly average wet weather quantity of effluent discharge shall not exceed 0.30 mgd.

Parameter	EFFLUENT LIMITATIONS Monthly Average	Weekly Average
Biochemical oxygen demand* (5 day)	30 mg/L, 35 lbs/day	45 mg/L, 53 lbs/day
Total Suspended Solids*	30 mg/L, 50 lbs/day	45 mg/L, 75 lbs/day
Fecal Coliform Bacteria	200/100 mL	400/100 mL
pH	Shall not be outside the range 6.0 to 9.0	

The monthly and weekly averages for BOD_5 and total suspended solids are based on the arithmetic mean of the samples taken. The averages for fecal coliform are based on the geometric mean of the samples taken.

*The monthly average effluent concentration limitations for BOD_5 and total suspended solids shall not exceed 30 mg/L or 15% of the respective influent concentrations, whichever is more stringent.

Total available (residual) chlorine shall be maintained which is sufficient to attain the fecal coliform limits specified above. Chlorine concentrations in excess of that necessary to reliably achieve these limits shall be avoided.

S2. TESTING SCHEDULE

The permittee shall monitor the wastewater according to the following schedule:

Parameter	Sample Point	Sampling Frequency	Sample Type
pH	influent	5/week	grab
	aeration basin	5/week	grab
	digester	5/week	grab
	effluent	5/week	grab
Dissolved Oxygen (DO)	influent	5/week	grab
	aeration basin	5/week	grab
	digester	5/week	grab
	RAS	5/week	grab
	effluent	5/week	grab
BOD_5	influent	2/month	24-hr. composite
	effluent	2/month	24-hr. composite
Suspended Solids	influent	2/month	24-hr. composite
	RAS	5/week	grab
	effluent	2/month	24-hr. composite
Flow	effluent	daily	continuous
Fecal Coliform	effluent	2/month	grab
Temperature F°	influent	5/week	grab
	aeration basin	5/week	grab
	digester	5/week	grab
Chlorine Residual	effluent	5/week	grab
SVI	aeration basin	5/week	grab
Mixed Liquor Suspended Solids (MLSS)	aeration basin	2/week	grab
	digester	2/month	grab
Volatile Suspended Solids (VSS)	aeration basin	2/week	grab
	digester	2/month	grab
30-Minute Settleability	aeration basin	5/week	grab
	digester	2/week	grab
Aeration Tank Concentration (ATC)	aeration basin	5/week	grab
Return Sludge Concentration (RSC)	aeration basin	5/week	grab

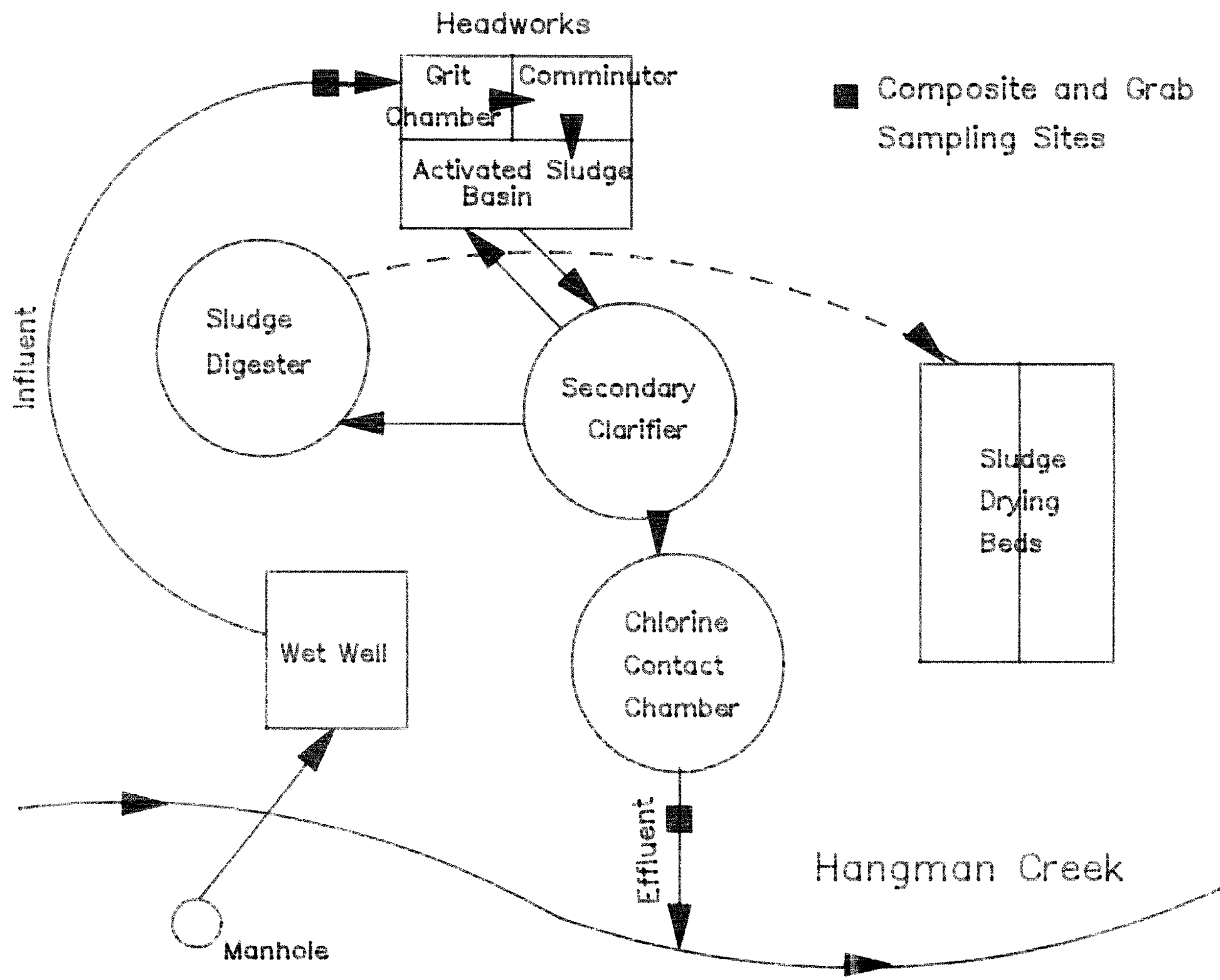

Figure 2. Layout of the Tekoa WTP showing locations of composite and grab sampling sites during the Tekoa WTP limited Class II survey on August 30-31, 1988.

WTP Methods

ISCO composite samplers were set up on the morning of August 30, 1988. Due to the intermittent inflow system, the influent sampler was programmed to collect a 120 mL sample every 10 minutes for the first five hours. The sample volume was increased to 200 mL for the remaining 19 hours to ensure an adequate final sample volume. The effluent sampler collected a 200 mL sample every 30 minutes during the same 24 hours. (Discharge appeared to be constant.) The Tekoa WTP operator collected about five grab samples of both influent and effluent during the day which were then composited. All samples were held at 4^{o}C until analyzed.

Receiving Water Methods

Hangman Creek grab samples were collected at six locations: two sites above the WTP and at Little Hangman Creek 0.2 mile upstream of the confluence as well as three sites below (Figure 1). Table 2 lists the sampling parameters measured at each site. Each site was sampled once on both sampling days except the site 400 feet below the WTP (RM 53.82) which was sampled three times: once on August 30, 1988 and twice in succession, (i.e. replicates), on August 31, 1988. Samples were obtained from mid-channel.

Flow at the WTP was estimated by two methods: (1) outflow at the V-notch weir measured three times during the study and (2) estimated flow based on the time the wet well pump operated during 24 hours. Streamflow was measured using a Marsh-McBirney flow meter and top-setting rod at four sites. Attempts were made to measure flow at the other two sites, but flow was below the level of instrument detection.

The volume of the slow-moving pool between RM 53.82 and 53.23 was estimated in order to calculate a time-of-travel through the stretch. Six depth transects were measured along the length of the pool.

Temperature, pH, and specific conductance were measured on site using Beckman meters for pH and specific conductance and a thermometer for temperature. Dissolved oxygen (D.O.) was determined using Winkler titration (azide modification of the iodometric method). Total residual chlorine was analyzed using a La Motte Palin DPD test kit (Detection limit: 0.1 mg/L).

All samples requiring laboratory analysis, including those from the WTP, were stored immediately on ice in the dark and were transported to the EPA/Ecology Laboratory in Manchester, Washington, within 24 hours. All samples were analyzed according to U.S. EPA (1983) and APHA *et al.* (1985). Kjeldahl-nitrogen samples were analyzed by a contract laboratory.

A D.O. survey was performed to observe maximum and minimum D.O. in the creek at dawn and late afternoon on August 31, 1988. Samples were collected at the six receiving water sites within 1.5 hours of each other. Temperature and pH were also measured.

Table 2. Sampling schedule for limited Class II and receiving water survey at Tekoa WTP.

Sample Type	Date	Time	Flow	Temp	pH	Cond	DO	Turb	TRC	BOD	COD	Nuts-3	Kjel-N	O&G	TS	TNVS	TSS	NVSS	Fecal
Class II																			
Infl. Grab	8/30	1045		X	X	X		X		X	X	X			X	X	X	X	
Infl. Comp.	8/30	1000	X																
	8/31	1000	X	X	X	X		X		X	X	X	X		X	X	X	X	
Effl. Grab	8/30	1000	X	X	X	X		X	X	X	X	X	X		X	X	X	X	X
	8/30	1520	X	X	X	X			X										X
	8/31	0830	X	X	X	X			X		X	X		X	X	X	X	X	X
Effl. Comp.	8/30	1000		X	X	X													
	8/31	1000	X	X	X	X		X		X	X	X	X		X	X	X	X	
Receiving Water																			
RM 0.2 (trib)	8/30	1430		X	X	X	X					X	X				X		X
	8/31	1230		X	X	X	X					X					X		X
RM 54.3	8/30	1340	X	X	X	X	X	X			X	X	X				X		X
	8/31	1230	X	X	X	X	X				X	X					X		X
RM 53.88	8/30	1125		X	X	X	X	X		X	X	X	X		X	X	X	X	X
	8/31	0925		X	X	X	X			X	X	X	X		X	X	X	X	X
RM 53.85	8/30	1145	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X
	8/31	0940	X	X	X	X	X				X	X	X		X	X	X	X	X
RM 53.82	8/30	1220	X	X	X	X	X	X			X	X	X				X		X
	8/31	1005	X	X	X	X	X			X	X	X	X				X		X
	8/31	1015	X	X	X	X	X				X	X	X				X		X
RM 53.23	8/30	1445	X	X	X	X	X	X			X	X	X				X		X
	8/31	1100	X	X	X	X	X				X	X					X		X

Macroinvertebrate populations were assessed at three sites near water quality sampling stations, one above and two below the WTP (Figure 1). Each site was a ponded area with tall canary grass along the banks. Methods similar to proposed rapid bioassessment techniques (Plafkin, *et al.* 1988) were used for sampling. A long-handled net (320 um mesh) was swept horizontally through a grassy bank area for exactly one minute to collect samples. Replicate samples were collected at each site. Contents of the net were carefully washed into a white tray. Two of the field crew analyzed the sample for ten minutes to get a sense of the number of each type of organism. Estimates of relative abundance (defined in Appendix D) were recorded. Representative organisms were also picked from the tray and preserved in 70 percent ethanol for later identification. Preserved representatives were identified to family using Merritt and Cummins (1978) and Pennak (1978).

Field work was conducted by Joe Joy, Ken Merrill, and Barbara Carey, all from Environmental Investigations and Laboratory Services Program (EILS), and Carl Nuechterlein and Deborah Cornett from Ecology's Eastern Regional Office (ERO). Otis Hampton, WTP Technical Assistance Specialist, conducted a review of the laboratory with the operator (Appendix A).

RESULTS AND DISCUSSION

Results of sampling on August 30-31, 1988, at the Tekoa WTP and Hangman Creek above and below the discharge are presented in this section. The findings are compared with water quality standards, WTP permit limits, and data from similar studies. A projection of conditions in the creek under Total Maximum Daily Load (TMDL), [full build-out and 7Q10 (7-day, 10-year low flow)], is also presented.

Major results for the WTP portion of the study are listed below followed by more detailed explanations.

- Despite weak influent strength, BOD and TSS loading and removal met permit requirements .

- Accumulated organic material in the chlorine contact chamber pits prevented effective disinfection and lead to extremely high fecal coliform bacteria levels in the effluent.

- The operator's flow estimates, using the influent pump timing method, overestimated actual flow by about 30 percent.

- Laboratory comparisons of BOD_5 analyses were acceptable, but TSS problems should be investigated.

- Nitrogen removal was higher than normal for an activated sludge plant.

Major results of the receiving water portion of the study are listed below followed by more detailed explanations.

- Effluent dilution ratio during the study was far below that recommended (1.6:1 compared to the recommended 100:1). Creek flow was 30 percent below the estimated 7Q10 flow.

- Violations of the D.O. standard (8 mg/L) were much more severe below the WTP discharge than above. Minimum upstream D.O. was 7.3 mg/L, while that below the WTP was 1.8 mg/L.

- Fecal coliform bacteria concentrations below the discharge far exceeded Class A standards due to solids accumulation and delayed removal in the chlorine contact chamber.

- Chlorine toxicity would have occurred downstream of the discharge had the chlorination system been operating normally.

- Macroinvertebrate samples indicated highly stressed conditions about 0.6 mile downstream of the discharge.

- Increased eutrophication occurred downstream of the WTP discharge based on nutrient loading and Nitrogen:Phosphorus (N:P) ratios.

- TMDL forecasts indicate violations of fecal coliform bacteria, chlorine, and D.O. standards. The predicted dilution ratio at WTP design capacity and the 7Q10 creek flow (1.4:1) is also below requirements.

Tekoa WTP Efficiency

Results for regulated parameters at the Tekoa WTP are shown in Table 3. Table 4 displays results of WTP water sampling. Appendix A contains results of the lab review.

BOD_5 and TSS

Despite weak influent strength, both biological oxygen demand (BOD_5) and total suspended solids (TSS) removal were within permit limits of 85 percent (Table 5). Treatment efficiencies were 87 percent for BOD_5 and 88 percent for TSS based on results of the 24-hour composite samples. Effluent loading for BOD_5 was less than half the dry-weather permitted limit of 35 lb/day. TSS loading was less than one-third the dry-weather limit of 50 mg/L.

The dilute nature of the summer influent (BOD_5 concentrations, Table 5) may be caused by settling in both the transport system (i.e., below the manhole, Figure 2) and wet well before being pumped to the headworks. Continued infiltration and inflow may also help explain the weak influent strength.

Influent BOD_5 split sample results showed good comparability between the Ecology lab and the WTP operator's lab in Colfax (Figure 3). However, Ecology's effluent BOD_5 sample was twice the value of the WTP sample when both samples were analyzed by the Ecology lab. Different sampling depths may explain the lower effluent value from the WTP

Table 3. NPDES compliance during limited Class II survey at the Tekoa WTP on August 30-31,1988.

		NPDES Limit		Effluent Quality (Ecology Results)	
Parameter	Units	Monthly Average	Weekly Average	Grab	Composite
BOD-5	mg/L	30	45	8	13
	lb/day	35	53		14
	% removal				
TSS	mg/L	30	45	5.5 *	13
	lb/day	50	75		14
	% removal				
Flow	MGD	0.2		0.095**	
Fecal coliform	#/100 ml	200	400	166,000 ***	
pH	S.U.	6.0<pH<9.0		7.5 **	
Total Residual Chlorine	mg/L	Sufficient to attain fecal coliform limits.		<0.1	

* Arithmetic mean of two samples, one collected on 8/30 and one one 8/31/88.
** Arithmetic mean of three samples.
*** Geometric mean of three samples.

Monthly average effluent limitations for BOD-5 and TSS shall not exceed 30 mg/L or 15% of the respective influent concentrations, whichever is more stringent.

Table 4. Results of Tekoa WTP sampling on August 30 and 31, 1988.

Treatment Plant Data

	INFLUENT					EFFLUENT						
Station Name	Ecology Comp* Ecology Lab	WTP Comp Ecology Lab	Ecology Comp Colfax Lab	WTP Comp Colfax Lab	Ecology Grab Ecology Lab	Ecology Comp Ecology Lab	WTP Comp Ecology Lab	Ecology Comp Colfax Lab	WTP Comp Colfax Lab	Ecology Grab-1	Ecology Grab-2	Ecology Grab-3
Time	24-hr	24-hr	24-hr	24-hr	1045	24-hr	24-hr	24-hr	24-hr	1000	1520	0830
Discharge (cfs)	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.16	0.15	0.14	0.15
Discharge (MGD)	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.09	0.10
Temperature ^{o}C					19.0					19.2	18.9	18.9
pH (S.U.) - Field	7.85	7.52			7.59	7.97	7.61			7.6	7.51	7.5
Specific Conductance												
(umhos/cm) - Field	345				450	304				235	395	377
(umhos/cm) - Lab	520	570			524	460	440			429		
Turbidity (NTU)	32	45			45	3	1			2		
Dissolved Oxygen												
(mg/L)										6.3	6.4	
(% sat)										74.0	75.0	
T. Residual Chlorine (mg/L) - Field										0.2	<0.1	<0.1
COD (mg/L)	180	92			230	23	20			21		
BOD_5 (mg/L)	100	100	89	92	140	13	5	8	8	8		
Ammonia-N (mg/L)	10	11			12	1.3	1.2			0.82		0.88
Un- Ammonia (mg/L)										0.012		0.010
Nitrate+Nitrite-N (mg/L)	0.36	0.18			0.25	0.08	0.09			0.08		0.08
Total Inorganic N (mg/L)	10.36	11.18			12.25	1.38	1.29			0.91		0.97
Kjeldahl-N (mg/L)	18.94				25.78	3.17	2.34			2.25		
Organic Nitrogen (mg/L)	8.94				13.78	1.87	1.14			1.43		
Total Nitrogen (mg/L)	19.3				26.00	3.01	1.23			1.51		
Total Phosphate (mg/L)	4.7	5.8			7.0	3.6	3.2			3.8		2.5
N:P ratio						0.84				0.83		
Chloride (mg/L)	25	31			23	25	23			22		25
Total solids (mg/L)	450	500			550	350	320			330		330
Total Nonvol. Solids	290	310			330	270	250			260		260
Non-vol. Susp. Solids	35	32			29	6	<1			2		2
Total Susp. Solids	110	120	81	137	190	13	1	13	17	7		4
Fecal coliform (#/100 mL)										1,100,000	70,000	59,000
Oil & grease (total grease fraction)												1.6

* = Composite sample

Table 5. BOD and TSS loading and removal efficiency results from composite samples collected by Ecology during limited Class II at the Tekoa WTP on August 30-31, 1988.

Parmeter	Ecology Lab Results Influent	Ecology Lab Results Effluent	Permitted Monthly Average	Tekoa Results Influent	Tekoa Results Effluent
Flow (cfs)	0.16	0.16	0.20	0.21	0.21
BOD-5 (mg/L)	100	13	30	92	8
TSS (mg/L)	110	13	30	152	13
BOD Load (lb/day)	79	10.3	35	102	8.9
TSS Load (lb/day)	87	10.3	50	169	14.4
BOD % Removal	87		85	91	
TSS % Removal	88		85	91	

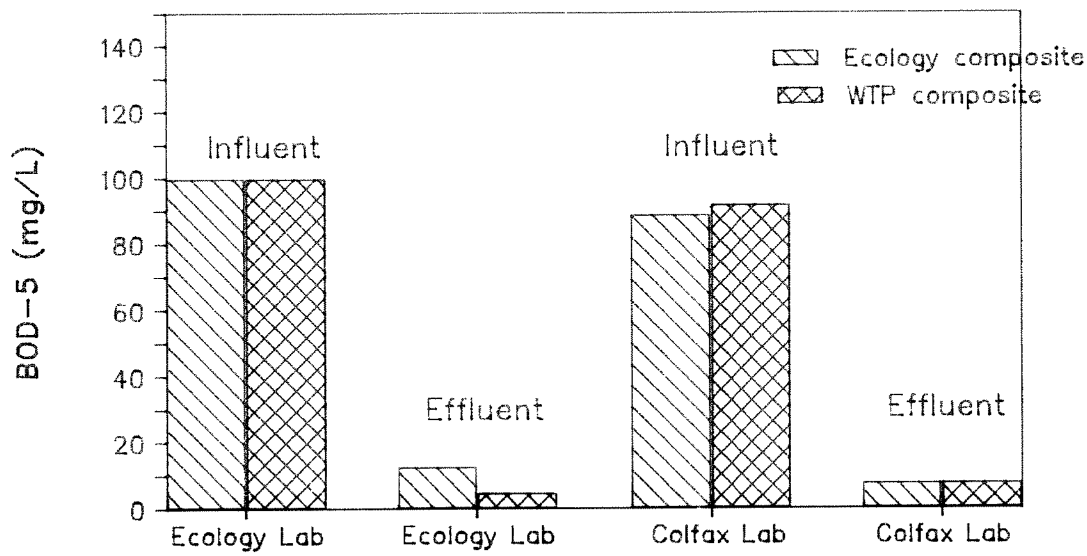

Figure 3. Results of BOD_5 composite samples split between Ecology's and the operator's laboratories. Composites were collected over 24 hours on August 30-31, 1988.

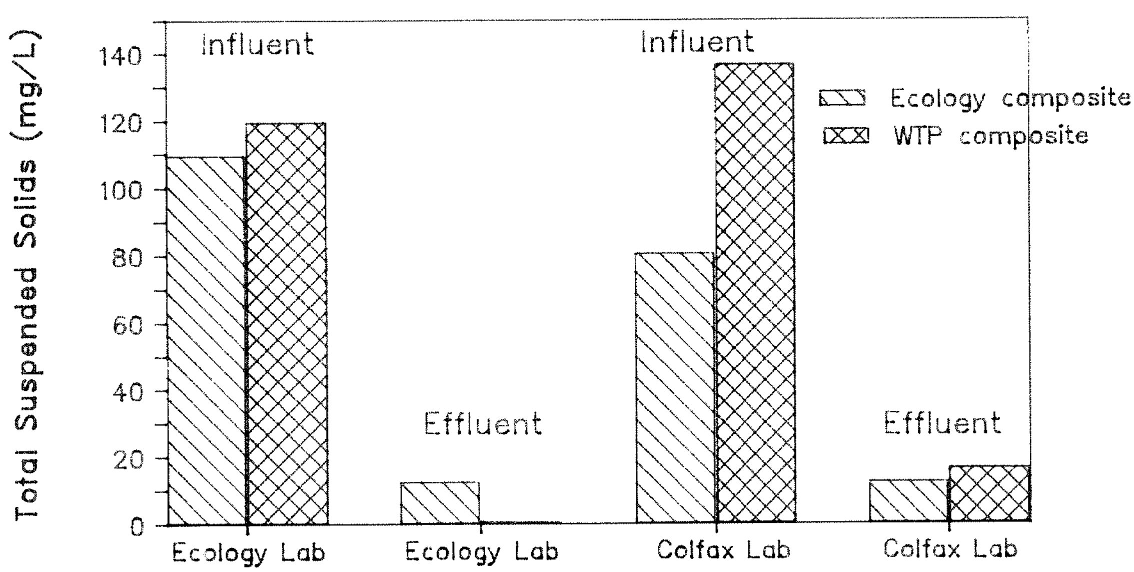

Figure 4. Results of total suspended solids composite samples split between Ecology's and the operator's laboratories. Composites were collected over 24 hours on August 30-31, 1988.

sample. Ecology's effluent composite sampling intake was located close to the bottom of the channel, while grab samples collected by the operator (and Ecology) were taken closer to the surface. In addition, turbidity and TSS which would be higher near the bottom than at the surface of the waste stream were also lower in the WTP sample. Grab samples collected by Ecology resulted in BOD_5 values similar to those of the operator results.

Interlaboratory comparison of TSS results were less favorable than those for BOD_5. The Colfax lab result substantially underestimated influent TSS concentration on the Ecology sample yet overestimated the value for the WTP sample (Figure 4). Effluent concentrations from the Colfax lab, 17 times higher than the Ecology lab result, were also unacceptable for the WTP sample. In contrast to the divergent results on the operator's sample, results for the Ecology split effluent for both labs were the same.

Some of the erroneous results for TSS may be related to filtering procedures used by the WTP operator. According to the Laboratory Procedures Review (Appendix A), filter clogging may be a problem. Filtering is conducted for 10 minutes before deciding that the filter is clogged. Five minutes is the recommended maximum. When a filter is clogged, a smaller volume of sample should be used with a new filter, rough side up.

Flow measurements made at the chlorine contact chamber weir were used for WTP loading calculations. Operator flow estimates based on the time the influent pumped were about 30 percent higher than weir-based estimates. Pump efficiency was not accounted for in the operator's flow calculation, although efficiency is typically less than 100 percent. Although less precise, hydraulic loading calculations based on streamflow measurements above and below the WTP likewise indicated a discharge rate closer to the weir-based estimate than that based on power consumption for both days. In order to increase record accuracy, it is recommended that WTP flow measurements be made using the V-notch weir rather than the pump timing technique.

Based on corrected monthly flow estimates for 1987 and 1988 (70 percent of WTP estimates), the Tekoa WTP is operating within its design capacity (Figure 5). However, according to daily Discharge Monitoring Reports (DMRs), plant flow occasionally exceeds even wet-weather capacity (0.3 MGD) for week-long periods; i.e., one period in February and one in April 1988.

Fecal Coliform Bacteria (FC) and Total Residual Chlorine (TRC)

Effluent FC concentrations were extremely high on both days. The geometric mean of three grab samples was 166,000 fc/100 mL, far exceeding the permitted 200 fc/100 mL. High FC levels resulted from large deposits of organic material in the chlorine contact chamber pits. Effective disinfection was not possible until the pits were pumped out in November 1988. Since November, DMRs indicate that effluent FC and TRC levels have met permit limits. The highest effluent FC level found during this study was 1,100,000 fc/100 mL.

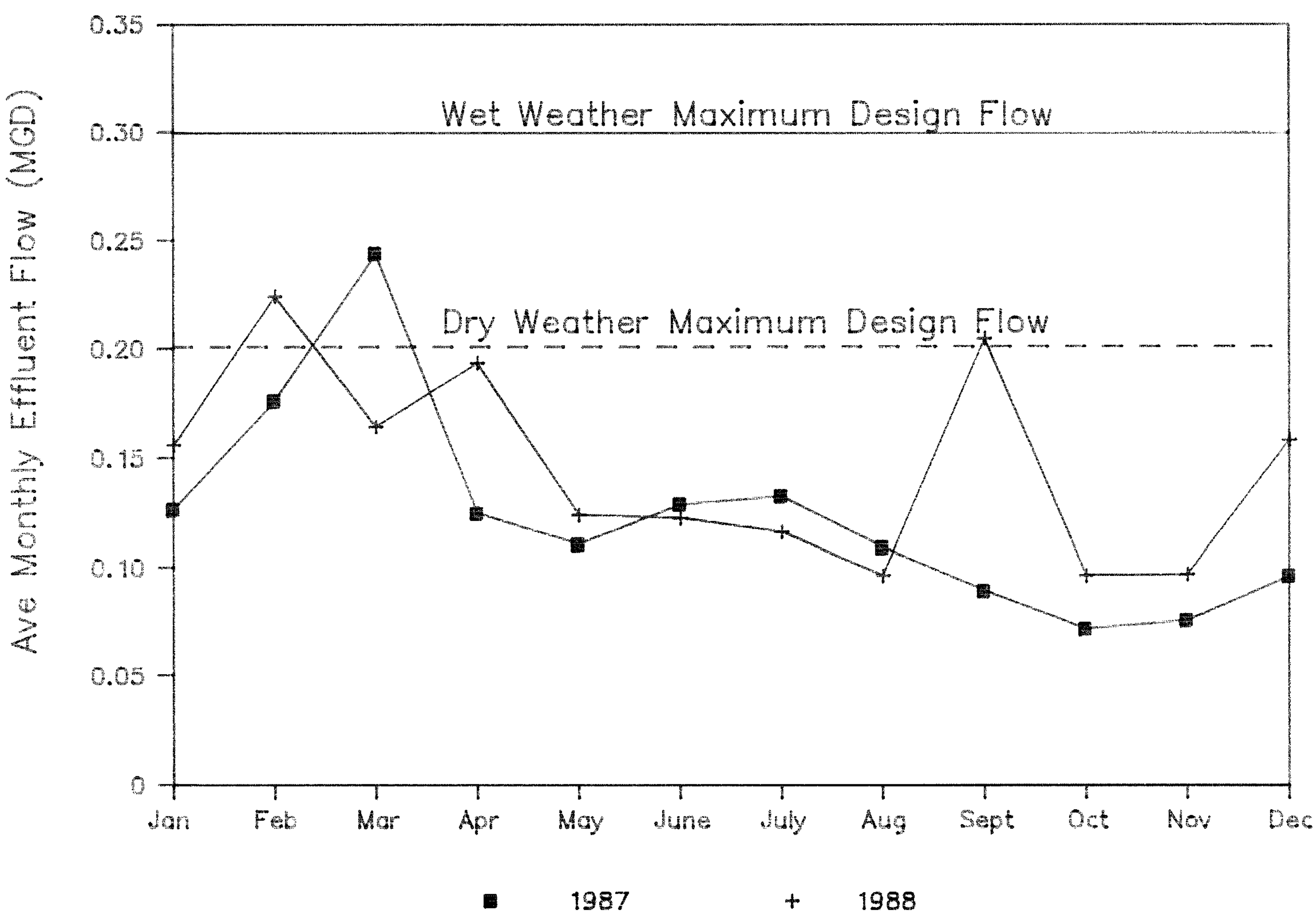

Figure 5. Average monthly effluent flow at the Tekoa WTP for 1987 and 1988. Values represent 70% of DMR values to account for pump efficiency.

High FC results such as those observed during the survey are reported as < 6,000 on DMRs rather than TNTC (too numerous to count) or > 6,000. This reporting discrepancy should be resolved.

Typical summertime effluent TRC levels at Tekoa were 0.2-0.5 mg/L according to DMRs for 1987 and 1988. Typical effluent FC concentrations ranged from 95 to 135 fc/100 mL.

Nutrients

Although not an intentional part of the treatment process, nitrogen removal during this survey was especially high for an activated sludge plant (Mills *et al.*, 1985). Typical nitrogen removal is about 35 percent. Both composite and grab samples indicated the removal at the Tekoa WTP was about 83 percent. Effluent inorganic nitrogen was 12 percent of that typical even for weak effluent from an activated sludge plant. Organic nitrogen was about 24 percent of typical.

Phosphorus removal (23 percent) was average for an activated sludge plant based on composite samples. Effluent phosphorus concentrations were about half of that typical for activated sludge plants (Mills *et al.*, 1985).

Higher-than-normal nitrogen removal combined with normal phosphorus removal leads to increased nitrogen limitation for primary producers downstream of the WTP. The ratio of total N:P for the effluent was 0.83 in both composite and grab samples. The median N:P ratio for such WTP's is 2.4 (Mills *et al.*, 1985). Further evidence of nitrogen loss during treatment is that the influent N:P ratio was close to that typical for dilute influent, while N:P for the effluent was less than 25 percent of typical.

Sludge Metals

Sludge metal values for five of six metals analyzed were below the geometric mean for municipal activated sludge plants in Washington (Table 6). Although nickel exceeded the geometric mean, it was within the range found in 29 activated sludge plants in Washington (Hallinan, 1988).

Temperature and D.O.

Influent and effluent temperatures were fairly constant, $19.0^{o}C$ +/- 0.2^{o}. High effluent temperature likely contributed to water quality violations in the receiving water, although the stations upstream of the discharge also exceeded the $18.0^{o}C$ standard in the afternoon. Effluent D.O. concentrations were relatively high ($\bar{x} =$ 6.4 mg/L, n = 2).

Effluent Effects on Hangman Creek

Low dilution at Tekoa during the survey (1.6:1) resulted in several water quality problems downstream of the WTP. Difficulties in flow analysis are outlined below, followed by areas of concern for receiving water quality.

Table 6. Comparison of sludge metals values observed at the Tekoa WTP on August 31, 1988 with values from other municipal activated sludge plants in Washington (mg/kg dry weight) (Hallinan, 1988).

		Geometric		Number
Metal	Tekoa WTP	Mean	Range	of Samples
Cadmium	4.6	7.6*	<0.1-25	34
Chromium	38.5	61.8	15-300	34
Copper	307	398	75-1,700	34
Lead	77.2	207	34-600	34
Nickel	53.6	25.5*	<0.1-62	29
Zinc	794	1,200	165-3,370	33

* "Less than" concentrations considered one-half the detection limit.

Flow

Streamflow in Upper Hangman Creek near the Tekoa WTP was, at best, near the lower level of instrument detection. Despite this fact, replicate flow measurements (two measurements taken a few minutes apart) at RM 53.82 were within two percent (Table 7). Likewise, measurements at the same stations on two consecutive days indicated differences of 10 percent or less.

Flow at the site immediately upstream of the discharge (RM 53.88) was not measurable with standard instrumentation. However, visual assessment of Rhodamine B dye added to the effluent indicated downstream flow as well as upstream dispersion for a short distance. The leading edge of dye traveled at about 100 ft/hr. Travel time slowed in the long, ponded reach between the discharge and RM 53.23 (0.5 mile stretch). Total travel time for the stretch was estimated as 6-7 days. (See Appendix B for time-of-travel calculations.) Flow at Little Hangman Creek was immeasurable but visible just above the RM 54.40 sampling site.

Since gauging and statistical information are not available for the upper reaches of Hangman Creek, flow was assumed to be proportional to the gauged flow at the mouth. During this survey flow at the mouth of Hangman Creek was 2.4 cfs (Drzymkowski, 1988), while that above the WTP was 0.09 cfs, or 3.8 percent of the flow at the mouth. The 7Q10 flow for the mouth station is 3.8 cfs, making the downstream flow during the survey 63 percent of the 7Q10. Flow upstream of the WTP was therefore assumed to be 63 percent of 7Q10 as well.

Dissolved Oxygen

Class A water quality standards for D.O. (8 mg/L, Ch. 173-201 WAC) were violated both above and below the discharge. Impacts of the WTP on D.O., including diel fluctuations, are evident in Figure 6. Early morning D.O. concentrations were lower than late afternoon at all creek stations. The lowest D.O. during the dawn/dusk survey, 1.9 mg/L, occurred about 400 feet downstream of the plant (RM 53.82). (Appendix C contains D.O. survey data.)

Deep, ponded conditions below the plant from RM 53.80 to RM 53.23 provide little aeration. Similar ponded conditions existed upstream of the discharge and in Little Hangman Creek. Heavy aquatic plant growth is likely responsible for a large night-time respiratory oxygen loss in these ponded areas. However, the lowest upstream D.O. concentration, not including the Little Hangman tributary (6.1 mg/L at RM 54.30, mean of duplicates), would have a much less harmful effect on the biota than the constant low concentrations below the WTP at RM 53.23 (1.9-3.4 mg/L). (See also "Macroinvertebrates" section below.)

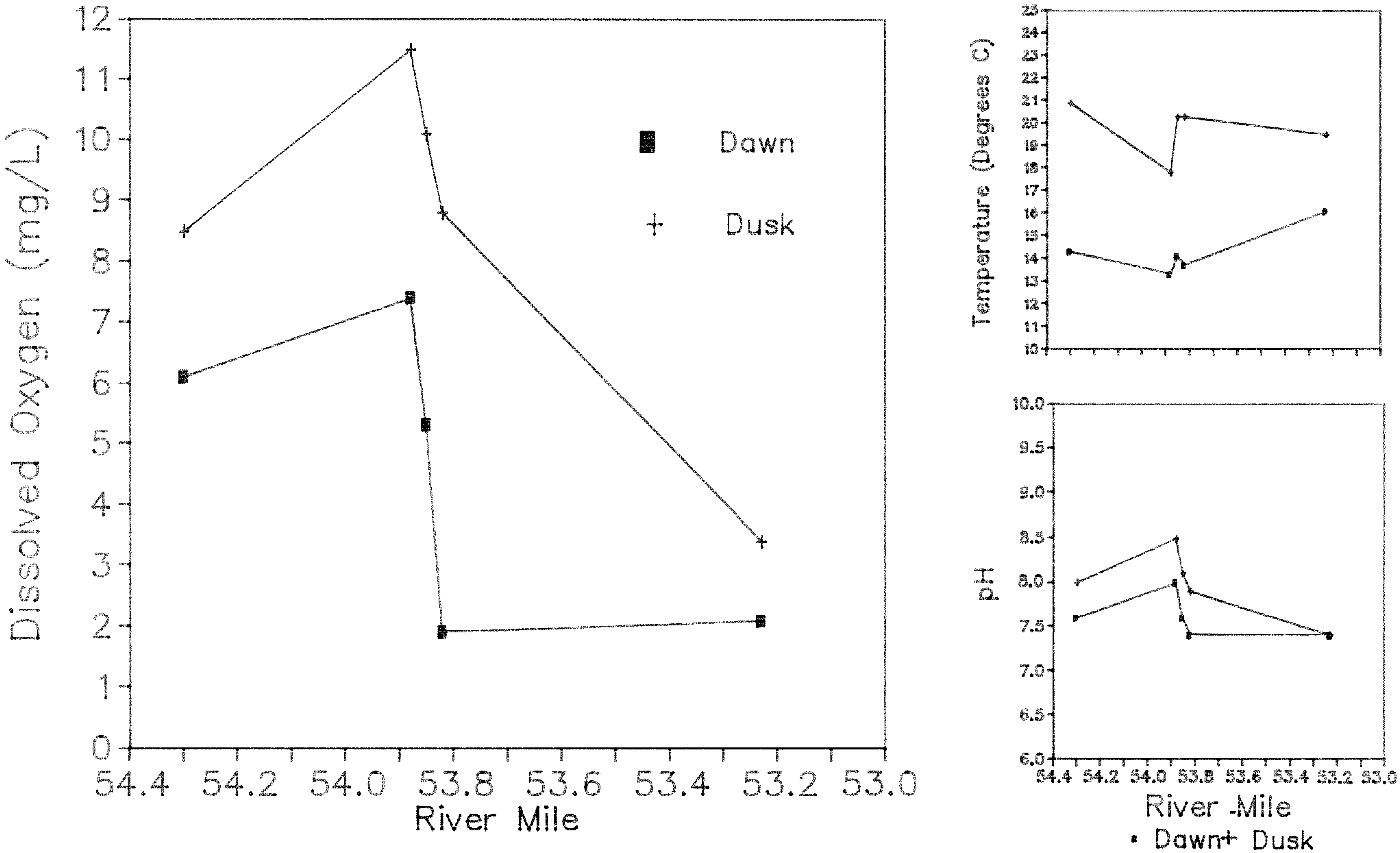

Figure 6. Dawn and dusk (late afternoon) dissolved oxygen concentration in Hangman Creek on August 31, 1988. Dawn values represent the mean of duplicate samples, while dusk values represent only one sample. Temperature and pH are shown at right.

Fecal Coliform Bacteria

Due to chlorination problems in the WTP, FC concentrations were 50 to 100 times higher than the Class A standard of 200 fc/100 mL (Ch. 173-201 WAC) at the two downstream stations closest to the outfall (RM 53.85 and 53.82). Even the station 150 feet upstream of the discharge (RM 53.88) had significantly higher fecal loading than the further upstream station (RM 54.30) (Figure 7, Table 8) indicating possible upstream dispersion of effluent and consequently bacteria. Cattle access along the entire stretch of the creek included in the study may also contribute to the higher than expected background fecal levels.

Fecal bacteria concentrations at the farthest downstream station, RM 53.23, were well below the Class A standard (Table 7). Although the six-day travel time probably prevented observation of effects from recent high fecal loading below the ponded stretch, ponding between RM 53.82 and 53.23 provides ideal conditions for bacteria settling and die-off.

Total Residual Chlorine

TRC was found in only one of three effluent grab samples. High effluent fecal coliform levels also indicated ineffective disinfection during the survey and for the following 2-1/2 months according to monthly DMRs. The cause for the chlorination malfunction is apparently related to emptying and cleaning the modified clarifier/chlorine contact chamber on August 29, 1988. Two sludge pits in the bottom of the chamber/clarifier had not been pumped for a few years and were not pumped on this occasion. However the pits were probably disturbed enough during the November cleaning to cause release of compounds such as hydrogen sulfide (H_2S) which reacts quickly with chlorine. Increasing chlorine dosage from six to eight lbs/day by the operator had little effect in either reducing the effluent fecal coliform bacteria concentration or increasing TRC until the pits were pumped on November 22, 1988. According to DMRs, both TRC and fecal coliform concentrations returned to permit levels the day after the pits were pumped.

If the Tekoa chlorination system had been operating normally, chlorine toxicity would have occurred below the outfall. Assuming typical effluent chlorine residual (0.1-0.5 mg/L) and dilution of 1.6:1, both acute and chronic U.S.EPA criteria are violated (U.S. EPA, 1986). At the current range of acceptable concentrations, upstream flow must be 13.7 cfs (160 times flows during this survey), to equal the four-day average concentration which is not to be exceeded more than once every three years.

Macroinvertebrates

Severe stress was evident in macroinvertebrate communities 0.6 mile downstream of the WTP outfall. Comparison of upstream (RM 53.88) and downstream (RM 53.83 and 53.23) macroinvertebrate communities showed severe stress at the site furthest downstream (RM 53.23) as measured by the Coefficient of Community Loss (COCL). The COCL was developed for assessing "harm" to aquatic environments due to effluent discharges (Courtemanch and Davies, 1987). Used successfully in other macro-invertebrate studies,

Table 7. Results of receiving water sampling at Hangman Creek and tributary on August 30-31/88.

River Mile	0.2		54.3		53.88		53.85		53.82			53.23	
Station Name	Little Hangman												
Date	8/30	8/31	8/30	8/31	8/30	8/31	8/30	8/31	8/30	8/31	8/31	8/30	8/31
Time	1430	1230	1340	1230	1125	0925	1145	0940	1220	1015	1005	1445	1100
Discharge (cfs)	*	*	0.080	0.091	**	**	0.199	0.210	0.286	0.270	0.275		0.263
Temperature (^oC)	16.0	16.2	18.4	18.7	20.0	15.0	20.0	16.5	19.5	15.6	15.6	19.0	18.4
pH (S.U.)	7.50	7.34	7.92	7.75	8.10	8.16	7.97	7.60	7.60	7.35	7.40	7.47	7.42
Spec. Cond.													
(umhos/cm) - Field	250	258	261	280	215	242	315	320	325	339	350	339	345
(umhos/cm) - Lab			298		300		395		385			374	
Dissolved Oxygen													
(mg/L)	3.0		8.0		8.4	8.1	9.1	6.0	5.5	3.2	3.0	2.4	2.3
(% sat)	33.1		92.6		100.4	87.5	108.8	66.9	65.1	35.0	32.8	28.1	26.6
BOD_5 (mg/L)					4	4	5				4		
COD (mg/L)					13	20	20	19	16	17	20	18	19
Ammonia-N (mg/L)	0.04	0.04	<0.01	0.01	0.15	0.12	0.48	0.62	0.48	0.76	0.77	0.08	0.08
Un- Ammonia (mg/L)	<0.0001	<0.0001		0.0001	0.007	0.005	0.017	0.007	0.007	0.005	0.006	0.001	0.001
Nitrate+Nitrite-N (mg/L)	0.01	0.01	0.01	<0.01	0.1	0.16	0.19	0.18	0.14	0.13	0.13	0.10	0.09
Total Inorganic N (mg/L)	0.05	0.05	0.01	0.01	0.26	0.29	0.69	0.81	0.63	0.90	0.91	0.18	0.17
Kjeldahl-N (mg/L)	7.8		0.53		0.71		0.70	1.51	1.47	1.52	1.95	1.74	0.74
Organic Nitrogen (mg/L)	7.76		0.53		0.56	0.58	1.03	0.85	1.04	1.19	0.97	0.66	
Total Nitrogen (mg/L)	7.81		0.55		0.82	0.87	1.72	1.66	1.67	2.09	1.88	0.84	
Total Phosphorus (mg/L)	0.16	0.09	0.06	0.06	0.18	0.13	2.6	2.2	2.3	2.5	2.5	0.92	0.86
Total N:P	48.8		9.0		4.5	6.7	0.7	0.8	0.7	0.8	0.8	0.9	
Chloride (mg/L)	3.1	3.2	4.6	4.2	5.1	4.8	16	19	17	19	20	18	
Turbidity (NTU)			2		4		2		3			6	
Total solids (mg/L)					210	210	280	290					
Total Non-vol. Solids (mg/L)					160	130	220	240					
Total Susp. Solids (mg/L)	22	9	7	2	6	6	6	3	2	1	1	13	16
Non-vol. Susp. Solids (mg/L)					4	4	3	<1					
Fecal coliform (#/100 mL)	120	160	17	29	900	120	16,000	20,000	10,000	13,000	13,000	49	55

*Flow below measurement detection level.
**Flow assumed to be same as upstream RM 54.3, since too low to measure.

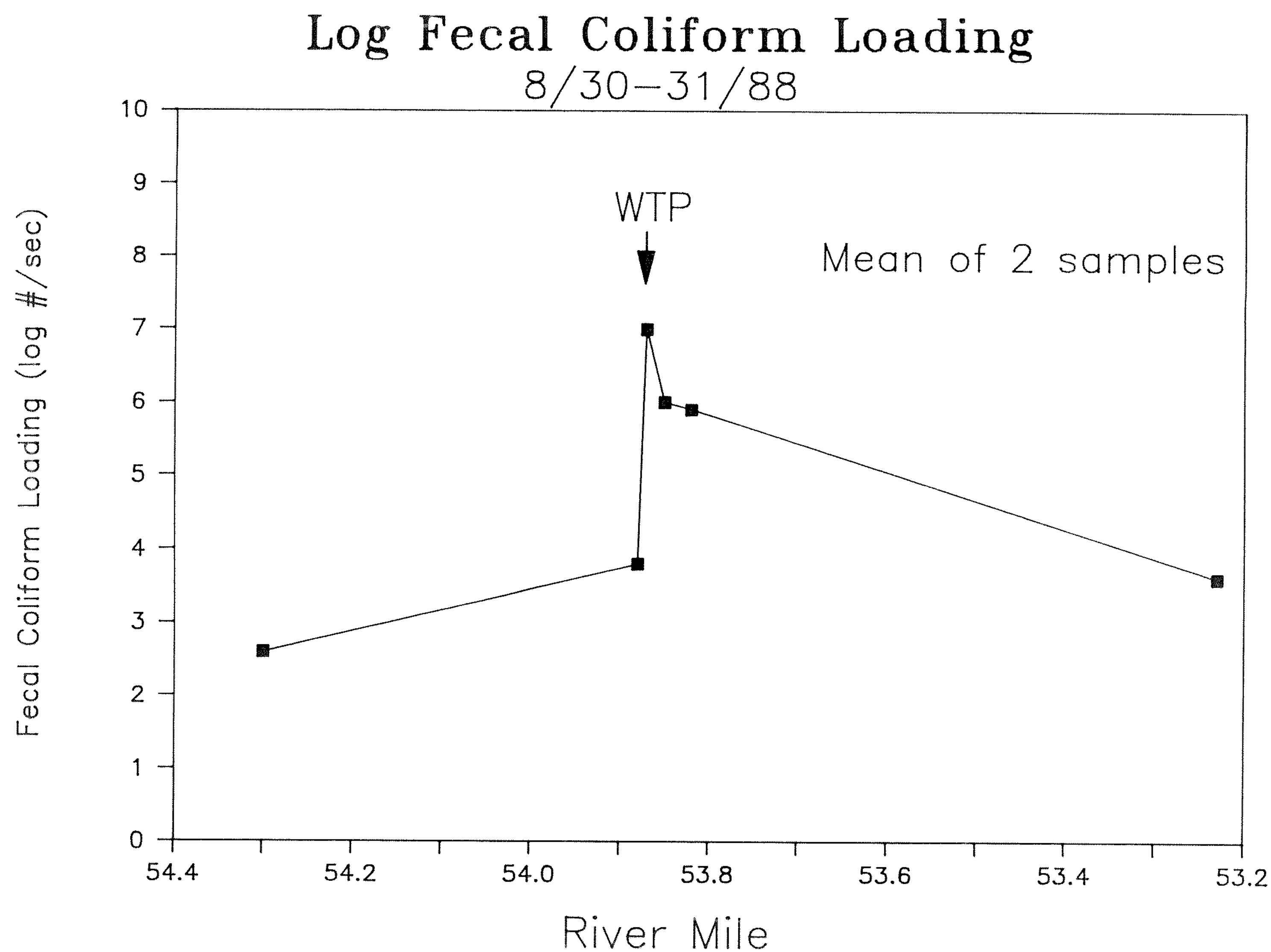

Figure 7. Fecal coliform bacterial loading (log units) in Hangman Creek above, below, and at the Tekoa WTP discharge. Values represent the mean of two samples collected on August 30 and 31, 1988.

Table 8. Loading estimates for Hangman Creek and Tekoa WTP effluent on August 30 and 31, 1988.

River Mile	54.30		53.88		53.87		53.85		53.82		53.23	
Date	8/30	8/31	8/30	8/31	8/30	8/31	8/30	8/31	8/30	8/31	8/30	8/31
Time	1340	1230	1125	0925			1145	0940	1220	1015	1445	1100
Discharge (cfs)	0.08	0.09	0.080	0.09	0.15	0.15	0.20	0.20	0.29	0.29	0.26	0.29
Discharge (MGD)	0.05	0.06	0.05	0.06	0.10	0.10	0.13	0.13	0.18	0.18	0.17	0.19
BOD_5 load (lb/day)			1.7	1.9	6.5		5.4		0.0	6.2		
COD load (lb/day)			5	10	17		21	20	25	29	25	30
Ammonia-N (mg/L)	0.01	0.00	0.15	0.06	0.82	0.71	0.48	0.67	0.48	1.19	0.08	0.13
Nitrate+Nitrite-N (lb/day)	0.00	0.00	0.04	0.08	0.06	0.06	0.20	0.19	0.22	0.20	0.14	0.14
Kjeldahl-N (lb/day)		0.26	0.30	0.34	0.74		1.62	1.58	2.34	2.85	1.04	
Total Phosphorus (lb/day)	0.03	0.03	0.08	0.06	3.07	2.02	2.79	2.36	3.55	3.85	1.29	1.34
Chloride (lb/day)	1.9	2.0	2.1	2.3	18	20	17	20	26	31	25	
T. Susp. Solids (lb/day)	2.9	1	2.5	3	11	3	6	3	3	2	18	25
Fecal coliform (#/sec)	338	649	17,906	2,686	41,035,500	2,200,995	791,861	989,826	711,282	924,667	3,168	3,967
Fecal coliform (log#/sec)	2.5	2.8	4.3	3.4	7.6	6.3	5.9	6.0	5.9	6.0	3.5	3.6

the COCL compares the number and types of taxa at two locations with similar habitat characteristics.

Courtemanch and Davies (1987) determined that COCL values exceeding 0.8 indicate significant stress and displacement of indigenous taxa when genus is used for comparison. The COCL resulting from comparison of macroinvertebrate populations upstream and downstream of the WTP (RM 53.88 compared to RM 53.23) was well above the stress thresholds at 1.1, probably due to oxygen depletion. This value may be somewhat biased due to grosser identification level, since organisms in this study were identified only to family. See Appendix C for coefficient calculations.

Abundance ratings for several taxa upstream of the discharge (RM 53.88) also differed from those 0.6 mile downstream (RM 53.23). Of particular note is the fact that chironomids (Order Diptera) were absent upstream of the discharge, abundant at the site 300 feet downstream and sparse at 0.6 mile downstream. Chironomids typically abound in organically enriched waters with adequate oxygen. Except early in the morning, D.O. was relatively high (7.3-11.5 mg/L) at the 300 feet downstream site (RM 53.83) but consistently low (1.9-3.4 mg/L) at 0.6 mile downstream. The oxygen/chironomid results therefore support the COCL indication of severe stress on the downstream community.

Nutrients

Nitrogen limitation downstream of the discharge is more pronounced than above as indicated by lower downstream N:P ratios (Figure 8). N:P ratios as low as those observed below the WTP ($\bar{x}$ = 0.8:1, n = 5) are usually found in hypereutrophic environments (Welch, 1980). Above the WTP however, N:P ratios were less severe ($\bar{x}$ = 5.7:1, n = 2) but also indicative of nitrogen limitation. Intensified nitrogen limitation downstream of secondary treatment discharges has also been found by Kendra (1988) as well as Crumpton and Isenhart (1987). In the latter study, algal uptake of ammonium and other nitrogen species was the primary explanation for the relative nitrogen scarcity. In this study however, ammonia was not a significant component of either the effluent nor upstream total nitrogen (Figure 9). High nitrogen removal in the WTP combined with limited upstream nitrogen supply appear to explain conditions in upper Hangman Creek.

Concentrations of N and P below the WTP also exceeded the eutrophic thresholds reported by Mills *et al.*, (1985): 0.92 mg/L for N and 0.13 mg/L for P. N and P levels above the WTP were close to the eutrophic range.

Nutrient loading estimates decreased at the downstream end of the ponded stretch (RM 53.23) (Figure 9). This decrease was probably due to settling, as well as uptake by macrophytes and algae. Although organic nitrogen in Little Hangman Creek exceeded the nitrogen threshold value for eutrophy by a factor of seven, low flows minimized loading to Hangman Creek.

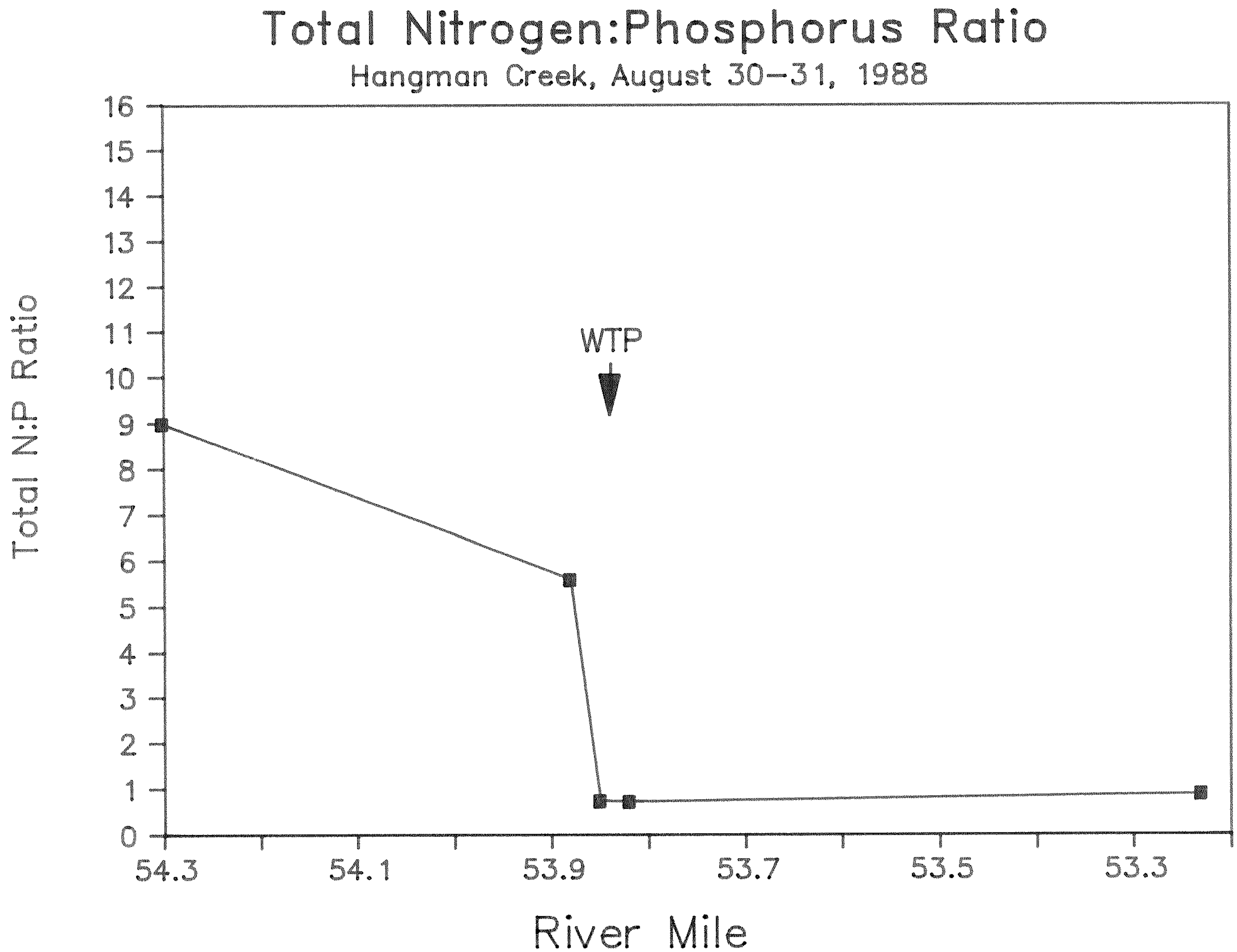

Figure 8. Ratios of total N:P in Hangman Creek during August 30-31, 1988. Values at RM 53.88, 53.85, and 53.82 represent the mean value for the two days, while the others represent one value.

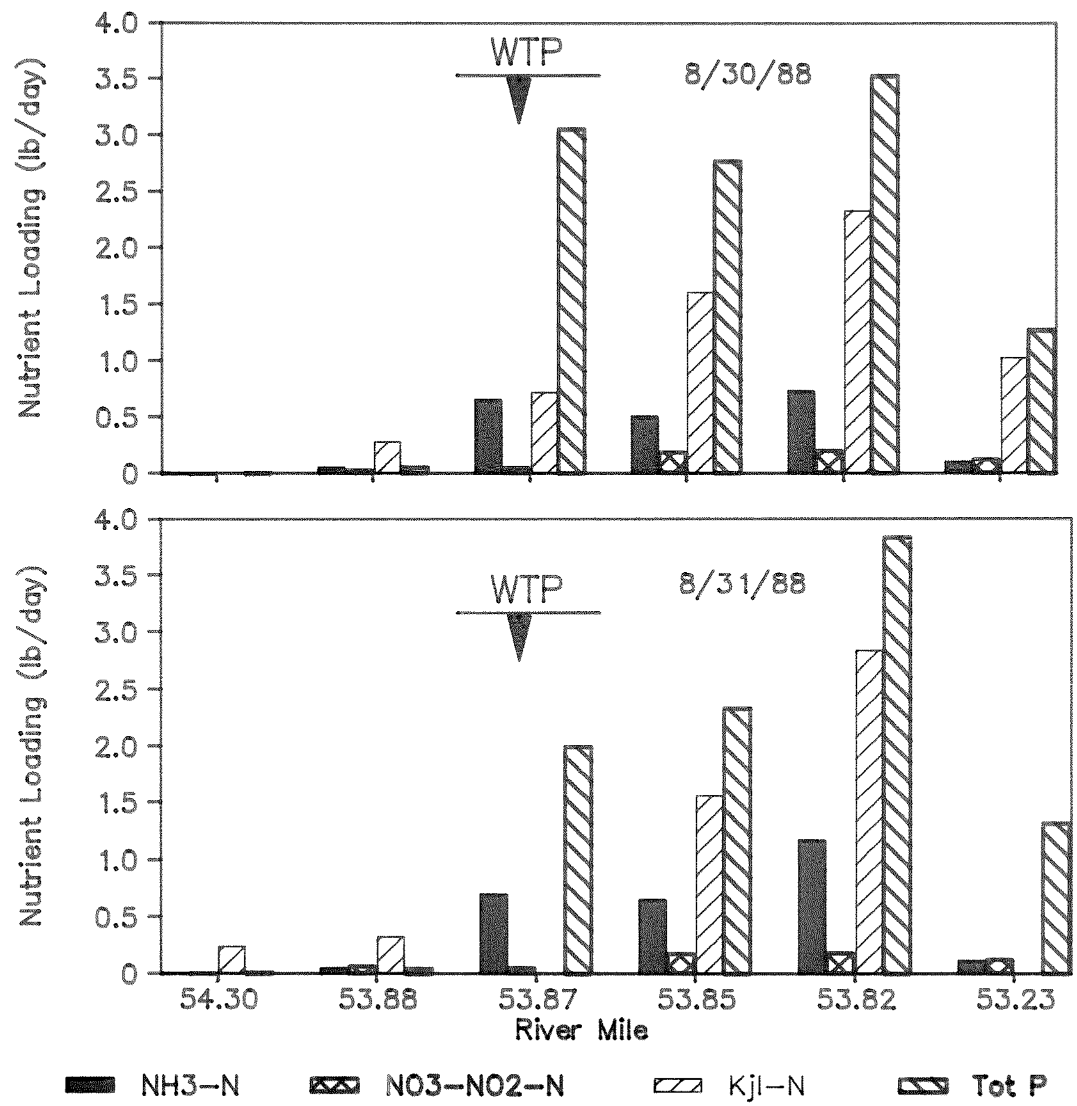

Figure 9. Nutrient loading in Hangman Crek above, below, and at the Tekoa WTP discharge. Kjeldahl-N samples were not collected on August 31, 1988, at RM 53.87 or 53.23.

Temperature

Class A temperature standards were violated even above the discharge. When "natural conditions" violate the 18°C standard, "natural conditions" become the criterion for the stream segment (Ch. 173-301-035). However, when natural temperature exceeds 18°C, human activities may not raise the temperature more than 0.3°C. The upstream maximum temperature in Hangman Creek, 20.9°C, was not exceeded downstream. Temperature violations may occur when the stream temperature is lower, since the effluent temperature during this study exceeded 18°C.

Total Maximum Daily Load (TMDL) Projections

Although estimated flow conditions in Hangman Creek were more severe than 7Q10 during the August 1988 survey, impacts of TMDL conditions at full population build-out and WTP design capacity, 0.2 MGD (double the capacity during the 1988 study), would be worse, or at best, similar to those observed. Violations of water quality standards would be expected for chlorine, fecal coliform bacteria, dissolved oxygen, and temperature. Increased nutrient loading would similarly exacerbate eutrophic conditions already present.

As previously mentioned, because no long-term gauging stations exist near the study site, flow in upper Hangman Creek is assumed to be proportional of the flow at the mouth, especially at relatively low flow. Streamflow at the mouth of Hangman Creek under 7Q10 conditions is 3.8 cfs; estimated flow above the Tekoa WTP 0.14 cfs. Under design flow dry weather conditions (0.2 MGD) and 7Q10 flow, the estimated dilution would be 1.4:1. These calculations assume that 100 percent of the upstream flow is used, although dilution zone guidelines specify that a maximum of only 15 percent of either volume or width of a receiving water can be used for dilution (Ecology, 1985).

Both chronic and acute criteria for TRC are violated under TMDL conditions (U.S. EPA, 1986). This estimate assumes a total residual chlorine effluent concentration of 0.1-0.5 mg/L, the recommended range for effective disinfection and 7Q10 flow conditions. A mass balance calculation was used to estimate the mixed concentration of TRC under TMDL conditions:

$$\text{Effluent Load} = \text{Mixed Load}$$

$$\text{OR}$$

$$(0.5 \text{ mg/L TRC})\ (0.33 \text{ cfs}) = (x \text{ mg/L})(0.47 \text{ cfs})$$

$$\begin{aligned} \text{Where } x &= \text{TRC concentration in the creek} \\ \text{Mixed flow} &= 0.33 \text{ cfs (maximum WTP flow, 0.2 MGD)} \\ &\quad + 0.14 \text{ cfs (7Q10 flow upstream of the WTP)} \end{aligned}$$

If the plant were operating at design capacity, streamflow 160 times greater than that observed during this study (14.7 cfs) would be necessary to dilute chlorine to the four-day, three-year average maximum criterion for TRC (U.S. EPA, 1986).

Under design conditions, the estimated fecal coliform concentration (147 fc/100 mL) meets the Class A standard. The following mass balance equation was used to estimate the TMDL fecal coliform concentration:

$$\text{Effluent Load} + \text{Upstream Creek Load} = \text{Mixed Load}$$

OR

$$(200\ \text{fc/100 mL})\ (0.33\ \text{cfs}) + (22\ \text{fc/100 mL})\ (0.14\ \text{cfs}) = (x\ \text{fc/100 mL})\ (0.47\ \text{cfs})$$

Where x = Fecal coliform concentration in the downstream mixed area

(The upstream fecal coliform concentration represents the geometric mean of two samples collected at RM 54.30, above the influence of the WTP. Upstream creek flow is the estimated 7Q10 flow above the WTP.)

D.O. depletion would be more severe under design conditions than during this survey. Composite and grab samples indicate that effluent BOD concentrations were only 20 to 40 percent of that permitted (30 mg/L). However, even at this relatively low effluent oxygen demand, downstream D.O. (1.9-3.4 mg/L) was far below the Class A standard. Upstream D.O. (RM 54.30 and 53.88) was also below the standard early in the morning, but far less depressed than the two stations farthest downstream (RM 53.82 and 53.23) (Figure 6).

A rough estimate of the projected D.O. depletion using the Streeter-Phelps D.O. model is contained in Table 9 (Mills, *et. al.*, 1985). Results of the model indicate that a minimum upstream flow of 2.0 cfs is needed to maintain a minimum of 7.2 mg/L D.O. downstream. The goal of 7.3 mg/L (the upstream D.O. minimum) could not be met with flows as high as 6 cfs. (See Appendix E for examples of model parameter inputs and outputs.)

Since streamflow, BOD and nitrogen data were only available for the very low flow conditions during this survey, data for higher flows and lower temperatures needed to run the model are based on best technical judgement. It should be noted that treatment plant nitrification may not be as effective at design capacity as during this study. Since D.O. concentrations upstream of the WTP were sometimes below 8.0 mg/L, natural conditions become the standard (Ch 173-201-035 WAC). The minimum D.O value at RM 53.88 (7.3 mg/L) was used in the model for upstream conditions as well as the model goal for downstream minimum D.O.

Additional data would be needed to determine statistically reliable model parameters. In order to provide a small margin of safety, the minimum suggested upstream flow rate for discharge is 2.8 cfs. This flow corresponds to a dilution ratio of 10:1.

Assuming that the flow at Hangman Creek mouth is consistently proportional to that upstream of the Tekoa WTP, that nitrification is as effective at design capacity as at 1/2 capacity, and that model coefficients are reasonable, the only time of year when the dilution ratio would exceed 10:1 with 90 percent confidence is February-April (U.S. Geological Survey, 1978). If only 50 percent confidence is needed, the discharge could be extended to the period December-May.

Table 9. Projected minimum D.O. concentrations in Hangman Creek downstream of the Tekoa WTP under various upstream flow conditions and permitted BOD loading. Upstream D.O. is assumed to be 7.3 mg/L.

Flow upstream of WTP (cfs)	0.09	0.15*	1.0	1.8	2.0	3.0	4.0
Flow at mouth (cfs)	2.4**	3.8	25	45	50	75	100
D.O. min (mg/L) at 0.2 MGD and permitted BOD (30 mg/L)***	0	0	5.7	6.8	7.2	7.2	7.2
D.O. min (mg/L) at 0.3 MGD and permitted BOD (30 mg/L)***	0	0	5.1	6.5	7.1	7.2	7.2

*Estimated 7-day, 10-year low flow.
**Flow on 8/30-31/88 (Drzymkowski, 1988)
***Effluent and upstream NOD loading assumed to be the same as 8/30-31/88

Additional nutrient loading expected under TMDL conditions would likely worsen the already deteriorated situation in the downstream reaches. Nuisance blue-green algae that can fix atmospheric nitrogen may become a greater problem. Further D.O. depletion would also be expected when primary producers decompose during the summer. Decomposing algae and aquatic plants could likewise cause an obnoxious odor problem. Nutrient inputs already exceed the creek's assimilative capacity as described previously.

Temperature of the effluent under design conditions should not significantly increase creek temperatures in late summer, since the upstream temperature maximum exceeded that for the effluent. However upstream temperatures are likely lower at times and the effluent may cause temperature violations.

SUMMARY AND CONCLUSIONS

Major findings of the August 1988 Tekoa WTP limited Class II inspection and receiving water survey include:

<u>Class II</u>

- BOD_5 and TSS loading and removal were within permit limits.

- Accumulated organic material in the chlorine contact chamber caused chemical reactions that prevented effective disinfection until November 1988. This problem resulted in extremely high fecal loading to the creek.

- The Colfax laboratory's TSS analysis overestimated low level effluent samples and underestimated high level influent samples.

- The operator's flow estimates, based on influent pump power consumption, were 30 percent higher than actual flows.

<u>Receiving Water</u>

- Low dilution exacerbated fecal coliform bacteria violations.

- Had the chlorine system been functioning normally, severe chlorine toxicity would have occurred during this survey. Unless a dechlorination system is installed, a dilution ratio exceeding 45:1 is necessary to prevent toxicity.

- Receiving water-to-effluent dilution was 1.6:1. (Streamflow during the study was 70 percent of the estimated 7Q10.)

- Severe D.O. violations occurred below the WTP. Slight violations occurred above the plant.

- Eutrophication was more severe below the WTP than upstream in terms of N:P ratio as well as nitrogen and phosphorus concentrations.

- Violations under TMDL conditions are expected for chlorine, fecal coliform bacteria and D.O. Higher nutrient loading would further strain the already stressed water body. Dilution under 7Q10 conditions (1.4:1) would also be inadequate.

RECOMMENDATIONS

The following activities are recommended to improve effectiveness of the Tekoa WTP operation and protection of Hangman Creek.

- Notification procedures included in the discharge permit were not followed during the 2-1/2 month period when fecal coliform bacteria exceeded permit discharge limits. The operator should review the permit conditions related to notifying Ecology whenever discharge limits are not met.

- Effluent flow should be measured at the V-notch weir at the end of the chlorine contact chamber.

- The ERO should notify the Colfax laboratory of split sample results. The TSS discrepancy should be investigated. Additional splits with the Ecology laboratory are recommended until influent TSS coefficients of variation are within five to 10 percent and effluent TSS coefficients of variation are within 33 percent (APHA, *et. al.* 1985).

- Although dilution is a problem at most eastern Washington WTP's and current plans do not allow for costly discharge removal at Tekoa, long-term plans should include at least seasonal effluent removal from Hangman Creek.

- Without chlorine removal, the minimum dilution should be 45:1. However, if chlorine removal is added, then effluent should be removed from the creek when dilution is less than 10:1 in order to minimize violations of D.O. standards. Assuming chlorine removal is added, dilution would be adequate for creek discharge from January through March. (In the fall of 1988, the USGS began semi-monthly flow measurements 3.3 miles upstream of Tekoa at Tensed, Idaho. These measurements may be useful in determining dilution ratios at Tekoa [Gudenberger, 1989].)

- Use of < and > signs for fecal coliform results on DMRs should be clarified with the operator. If other designations are more useful for DMR tracking and data analysis, ERO should request that the operator use such designations.

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APPENDICES

Appendix A. **Laboratory Procedure Review Sheet**

Discharger: Tekoa

Date: 8-30-88

Discharger representative: Janet Layton

Ecology reviewer: Otis Hampton

Instructions

Questionnaire for use reviewing laboratory procedures. Circled numbers indicate work is needed in that area to bring procedures into compliance with approved techniques. References are sited to help give guidance for making improvements. References sited include:

Ecology = Department of Ecology Laboratory User's Manual, December 8, 1986.

SM = APHA-AWWA-WPCF, Standard Methods for the Examination of Water and Wastewater, 16th ed., 1985.

SSM = WPCF, Simplified Laboratory Procedures for Wastewater Examination, 3rd ed., 1985.

Sample Collection Review

1. Are grab, hand composite, or automatic composite samples collected for influent and effluent BOD and TSS analysis? hand Composite

2. If automatic compositor, what type of compositor is used?
   The compositor should have pre and post purge cycles unless it is a flow through type. Check if you are unfamiliar with the type being used.

3. Are composite samples collected based on time or flow?

4. What is the usual day(s) of sample collection?
   Wed. & Thursday

5. What time does sample collection usually begin?
   8:00 - 9:00 am

6. How long does sample collection last?
   8 hours

7. How often are subsamples that make up the composite collected?
   1-2 hours

8. What volume is each subsample?
   500 ml

9. What is the final volume of sample collected?
   4.0 Liters

10. Is the composite cooled during collection?
    yes

11. To what temperature? 4° C
The sample should be maintained at approximately 4 degrees C (SM p41, #5b: SSM p2).

12. How is the sample cooled?
Mechanical refrigeration or ice are acceptable. Blue ice or similar products are often inadequate.

13. How often is the temperature measured? daily
The temperature should be checked at least monthly to assure adequate cooling.

14. Are the sampling locations representative?
yes

15. Are any return lines located upstream of the influent sampling location? no
This should be avoided whenever possible.

16. How is the sample mixed prior to withdrawal of a subsample for analysis?
The sample should be thoroughly mixed.

17. How is the subsample stored prior to analysis?
The sample should be refrigerated (4 degrees C) until about 1 hour before analysis, at which time it is allowed to warm to room temperature.
warmed for 1 hour

18. What is the cleaning frequency of the collection jugs? after each use
The jugs should be thoroughly rinsed after each sample is complete and occasionally be washed with a non-phospate detergent.

19. How often are the sampler lines cleaned?
NA Rinsing lines with a chlorine solution every three months or more often where necessary is suggested.

pH Test Review

1. How is the pH measured?
A meter should be used. Use of paper or a colorimetric test is inadequate and those procedures are not listed in Standard Methods (SM p429).

2. How often is the meter calibrated?
The meter should be calibrated every day it is used.

3. What buffers are used for calibration? 4 & 7
Two buffers bracketing the pH of the sample being tested should be used.

If the meter can only be calibrated with one buffer, the buffer closest in pH to the sample should be used. A second buffer, which brackets the pH of the sample should be used as a check. If the meter cannot accurately determine the pH of the second buffer, the meter should be repaired.

BOD Test Review

1. What reference is used for the BOD test?
Standard Methods or the Ecology handout should be used.

2. How often are BODs run? 2/month
The minimum frequency is specified in the permit.

3. How long after sample collection is the test begun?
The test should begin within 24 hours of composite sample completion (Ecology Lab Users Manual p42). Starting the test as soon after samples are complete is desirable.

4. Is distilled or deionized water used for preparing dilution water?

5. Is the distilled water made with a copper free still? yes
Copper stills can leave a copper residual in the water which can be toxic to the test (SSM p36).

6. Are any nitrification inhibitors used in the test? no What?
2-chloro-6(trichloro methyl) pyridine or Hach Nitrification Inhibitor 2533 may be used only if carbonaceous BODs are being determined (SM p 527, #4g: SSM p 37).

6. Are the 4 nutrient buffers or powder pillows used to make dilution water?
If the nutrients are used, how much buffer per liter of dilution water are added?
1 mL per liter should be added (SM p527, #5a: SSM p37).

7. How often is the dilution water prepared? made fresh
Dilution water should be made for each set of BODs run.

8. Is the dilution water aged prior to use? no
Dilution water with nitrification inhibitor can be aged for a week before use (SM p528, #5b).
Dilution water without inhibitor should not be aged.

9. Have any of the samples been frozen? no
If yes, are they seeded?
Samples that have been frozen should be seeded (SSM p38).

10. Is the pH of all samples between 6.5 and 7.5? yes 7.0 - 7.1
If no, is the sample pH adjusted?
The sample pH should be adjusted to between 6.5 and 7.5 with 1N NaOH or 1N H_2SO_4 if 6.5 > pH >7.5 if caustic alkalinity or acidity is present (SM p529, #5e1: SSM p37).
High pH from lagoons is usually not caustic. Place the sample in the dark to warm up, then check the pH to see if adjustment is necessary.

If the sample pH is adjusted, is the sample seeded? yes
The sample should be seeded to assure adequate microbial activity if the pH is adjusted (SM p528, #5d).

11. Have any of the samples been chlorinated or ozonated? yes

If chlorinated are they checked for chlorine residual and dechlorinated as necesssary? by DPD

How are they dechlorinated? no Residual shows with DPD

Samples should be dechlorinated with sodium sulfate (SM p529, #5e2: SSM p38), but dechlorination with sodium thiosulfate is common practice. Sodium thiosufate dechlorination is probably acceptable if the chlorine residual is < 1-2 mg/L.

If chlorinated or ozonated, is the sample seeded? yes

The sample should be seeded if it was disinfected (SM p528, #5d&5e2: SSM p38).

12. Do any samples have a toxic effect on the BOD test? no

Specific modifications are probably necessary (SM p528, #5d: SSM p37).

13. How are DO concentrations measured?

If with a meter, how is the meter calibrated?

Air calibration is adequate. Use of a barometer to determine saturation is desirable, although not manditory. Checks using the Winkler method of samples found to have a low DO are desirable to assure that the meter is accurate over the range of measurements being made.

How frequently is the meter calibrated?

The meter should be calibrated before use.

14. Is a dilution water blank run? yes

A dilution waater blank should always be run for quality assurance (SM p527, #5b: SSM p40, #3).

What is the usual initial DO of the blank? 8.9 - 9.1 mg/L

The DO should be near saturation; 7.8 mg/L @ 4000 ft, 9.0 mg/L @ sea level (SM p528, #5b). The distilled or deionized water used to make the dilution water may be aged in the dark at ~20 degrees C for a week with a cotton plug in the opening prior to use if low DO or excess blank depletion is a problem. @ 20°C This Elev. 8.4 mg/L

What is the usual 5 day blank depletion? .2 → .5 mg/L

The depletion should be 0.2 mg/L or less. If the depletion is greater, the cause should be found (SM p527-8, #5b: SSM p41, #6).

15. How many dilutions are made for each sample? 1

At least two dilutions are recommended. The dilutions should be far enough apart to provide a good extended range (SM p530, #5f: SSM p41).

16. Are dilutions made by the liter method or in the bottle?

Either method is acceptable (SM p530, #5f).

17. How many bottles are made at each dilution? 3

How many bottles are incubated at each dilution? 2

When determining the DO using a meter only one bottle is necessary. The DO is measured, then the bottle is sealed and incubated (SM p530, #5f2).

When determining the DO using the Winkler method two bottles are necessary. The initial DO is found of one bottle and the other bottle is sealed and incubated (Ibid.).

18. Is the initial DO of each dilution measured? yes
What is the typical initial DO? 8.6 mg/L
The initial DO of each dilution should be measured. It should approximate saturation (see #14).

1.0 - 2.0

19. What is considered the minimum acceptable DO depletion after 5 days?
What is the minimum DO that should be remaining after 5 days?
The depletion should be at least 2.0 mg/L and at least 1.0 mg/L should be left after 5 days (SM p531, #6: SSM p41).

20. Are any samples seeded? yes
Which? Effluent
What is te seed source? secondary Clarifier
Primary effluent or settled raw wastewater is the preferred seed. Secondary treated sources can be used for inhibited tests (SM p528, #5d: SSM p41).

X How much seed is added to each sample? 5 mls
Adequate seed should be used to cause a BOD uptake of 0.6 to 1.0 mg/L due to seed in the sample (SM p529, #5d).

How is the BOD of the seed determined? not determined
Dilutions should be set up to allow the BOD of the seed to be determined just as the BOD of a sample is determined. This is called the seed control (SM p529, #5d: SSM p41).

21. What is the incubator temperature? 20°C ± 1
The incubator should be kept at 20 +/- 1 degree C (SM p531, #5i: SSM p40, #3).

How is incubator temperature monitored?
A thermometer in a water bath should be kept in the incubator on the same shelf as the BODs are incubated.

How frequently is the temperature checked? 1/week
The temperature should be checked daily during the test. A temperature log on the incubator door is recommended.

How often must the incubator temperature be adjusted? infrequent
Adjustment should be infrequent. If frequent adjustments (every 2 weeks or more often) are required the incubator should be repaired.

Is the incubator dark during the test period? yes
Assure the switch that turns off the interior light is functioning.

22. Are water seals maintained on the bottles during incubation? yes
Water seals should be maintained to prevent leakage of air during the incubation period (SM p531, #5i: SSM p40, #4).

23. Is the method of calculation correct?
Check to assure that no correction is made for any DO depletion in the blank and that the seed correction is made using seed control data.

Standard Method calculations are (SM p531, #6):

for unseeded samples;

$$\text{BOD (mg/L)} = \frac{D1 - D2}{P}$$

for seeded samples;

$$\text{BOD (mg/L)} = \frac{(D1 - D2) - (B1 - B2)f}{P}$$

Where: D1 = DO of the diluted sample before incubation (mg/L)
D2 = DO of diluted sample after incubation period (mg/L)
P = decimal volumetric fraction of sample used
B1 = DO of seed control before incubation (mg/L)
B2 = DO of seed control after incubation (mg/L)

$$f = \frac{\text{amount of seed in bottle D1 (mL)}}{\text{amount of seed in bottle B1 (mL)}}$$

Total Suspended Solids Test Review

Preparation

1. What reference is used for the TSS test? State Handout, Standard methods

2. What type of filter paper is used? Whatman GFC
Std. Mthds. approved papers are: Whatman 934AH (Reeve Angel), Gelman A/E, and Millipore AP-40 (SM p95, footnote: SSM p23)
4.7 cm Whatman 934AH is available - will use

3. What is the drying oven temperature?
The temperature should be 103-105 degrees C (SM p96, #3a: SSM p23).

4. Are any volatile suspended solids tests run? yes
If yes--What is the muffle furnance temperature?
The temperature should be 550+/- 50 degrees C (SM p98, #3: SSM p23).

5. What type of filtering apparatus is used?
Gooch crucibles or a membrane filter apparatus should be used (SM p95, #2b: SSM p23).

6. How are the filters pre-washed prior to use? 75 ml distilled H_2O
The filters should be rinsed 3 times with distilled water (SM p23, #2: SSM p23, #2).

Are the rough or smooth sides of the filters up?
The rough side should be up (SM p96, #3a: SSM p23, #1)

How long are the filters dried? 1. 1.0 hour
The filters should be dried for at least one hour in the oven. An additional 20 minutes of drying in the furnance is required if volatile solids are to be tested (Ibid).

How are the filters stored prior to use?
The filters should be stored in a dessicator (Ibid).

7. How is the effectiveness of the dessicant checked?
All or a portion of the dessicant should have an indicator to assure effectiveness.
blue

Test Procedure

8. In what is the test volume of sample measured?
The sample should be measured with a wide tipped pipette or a graduated cylinder.

9. Is the filter seated with distilled water? yes
The filter should be seated with distilled water prior to the test to avoid leakage along the filter sides (SM p97, #3c).

10. Is the entire measured volume always filtered? yes
The entire volume should always be filtered to allow the measuring vessel to be properly rinsed (SM p97, #3c: SSM p24, #4).

11. What are the average and minimum volumes filtered?

	Volume	
	Minimum	Average
Influent	20	50
Effluent	50	100

12. How long does it take to filter the samples?

	Time
Influent	5 min.
Effluent	1 min.

13. How long is filtering attempted before deciding that a filter is clogged? 10 min
Prolonged filtering can cause high results due to dissolved solids being caught in the filter (SM p96, #1b). We usually advise a five minute filtering maximum.

14. What do you do when a filter becomes clogged? start over
The filter should be discarded and a smaller volume of sample should be used with a new filter.

15. How are the filter funnel and measuring device rinsed onto the filter following ~~sample addition?~~
Rinse 3x's with approximately 10 mLs of distilled water ~~each time~~ (? ?).

16. How long is the sample dried? 1.0 hour
The sample should be dried at least one hour for the TSS test and 20 minutes for the volatile test (SM p97, #3c; p98, #3: SSM p24, #4). Excessive drying times (such as overnight) should be avoided.

17. Is the filter thoroughly cooled in a dessicator prior to weighing? yes
The filter must be cooled to avoid drafts due to thermal differences when weighing (SM p97, #3c: SSM p97 #3c).

18. How frequently is the drying cycle repeated to assure constant filter weight has ben reached (weight loss <0.5 mg or 4%, whichever is less: SM p97, #3c)? is not routine
We recommend that this be done at least once every 2 months.

19. Do calculations appear reasonable? yes
Standard Methods calculation (SM p97, #3c).

$$\text{mg/L TSS} = \frac{(A - B) \times 1000}{\text{sample volume (mL)}} \quad \times 1000$$

where: A= weight of filter + dried residue (mg)
B= weight of filter (mg)

Fecal Coliform Test Review

1. Is the Membrane Filtration (MF) or Most Probable Number (MPN) technique used?
   This review is for the MF technique.

2. Are sterile techniques used? yes

3. How is equipment sterilizated? auto clave
   Items should be either purchased sterilized or be sterilized. Steam sterilization, 121 degrees C for 15 to 30 minutes (15 psi); dry heat, 1-2 hours at 170 degrees C; or ultraviolet light for 2-3 minutes can be used. See Standard Methods for instruclions for specific items (SSM p67-68).

4. How is sterilization preserved prior to item use?
   Wrapping the items in kraft paper or foil before they are sterilized protects them from contamination (Ibid.).

5. How are the following items sterilized?

	Purchased Sterile	Sterilized at Plant
Collection bottles		✓
Phosphate buffer		✓
Media	✓	
Media pads	✓	
Petri dishes	✓	✓
Filter apparatus		
Filters	✓	
Pipettes	—	✓
Measuring cylinder		✓
Used petri dishes		

6. How are samples dechlorinated at the time of collection?
   Sodium thiosulfate (1 mL of 1% solution per 120 mLs (4 ounces) of sample to be collected) should be added to the collection bottle prior to sterilization (SM p856, #2: SSM p68, sampling).

7. Is phosphate buffer made specifically for this test? yes
   Use phosphate buffer made specifically for this test. The phosphate buffer for the BOD test should not be used for the coliform test (SM p855, #12: SSM p66).

8. What kind of media is used? millipore mF-C
   M-FC media should be used (SM p896, SSM p66).

9. Is the media mixed or purchased in ampoules?
   Ampoules are less expensive and more convient for under 50 tests per day (SSM p65, bottom).

10. How is the media stored? Refrigerator
    The media should be refrigerated (SM p897, #1a: SSM p66, #5).

6 months

11. How long is the media stored? ~~1 year~~ manufacturers expiration date
Mixed media should be stored no longer than 96 hours (SM p897, #1a: SSM p66, #5). Ampoules will usually keep from 3-6 months -- read ampoule directions for specific instructions.

12. Is the work bench disinfected before and after testing? yes
This is a necessary sanitazation procedure (SM p831, #1f).

13. Are forceps dipped in alcohol and flamed prior to use? yes
Dipping in alcohol and flaming are necessary to sterilize the forceps (SM p889, #1: SSM p73, #4).

14. Is sample bottle thoruoghly shaken before the test volume is removed? The sample should be mixed thoroughly (SSM p73, #5). yes

15. Are special procedures followed when less than 20 mLs of sample is to be filtered? yes buffer is added
10-30 mLs of sterile phosphate buffer should be put on the filter. The sample should be put into the buffer water and swirled, then the vacuum should be turned on. More even organism distribution is attained using this technique (SM p890, #5a: SSM P73, #5).

16. Are special procedures followed when less than 1 mL of sample is to be filtered? NA
Sample dilution is necessary prior to filtration when <1 mL is to be tested (SM p864, #2c: SSM p69).

17. Is the filter apparatus rinsed with phosphate buffer after sample filtration? yes
Three 20-30 mL rinses of the filter apparatus are recommended (SM p891, #5b: SSM p75, #7).

18. How soon after sample filtration is incubation begun? 10 min.
Incubation should begin within 20-30 minutes (SM p897, #2d: SSM p77, #10 note).

19. What is the incubation temperature?
44.5 +/- 0.2 degrees C (SM p897, #2d: SSM p75, #9).

20. How long are the filters incubated?
24 +/- 2 hours (Ibid.).

21. How soon after incubation is complete are the plate counts made? immediately
The counts should be made within 20 minutes after incubation is complete to avoid colony color fading (SSM p77, FC).

22. What color colonies are counted? blue
The fecal coliform colonies vary from light to dark blue (SM p897, #2e: SSM p78).

23. What magnification is used for counting?
10-15 power magnification is recommended (SM p898, #2e: SSM p78).

24. How many colonies blue colonies are usually counted on a plat(40-50
Valid plate counts are between 20 and 60 colonies (SM p897, #. p78).

25. How many total colonies are usually on a plate? <200
The plate should have <200 total colonies to avoid inhabition crowding (SM p893, #6a: SSM p63, top).

26. When calculating results, how are plates with <20 or >60 colonies considered when plates exist with between 20 and 60 colonies? discarded
In this case the plates with <20 or >60 colonies should not be calculations (SM p898, #3: SSM p78, C&R).

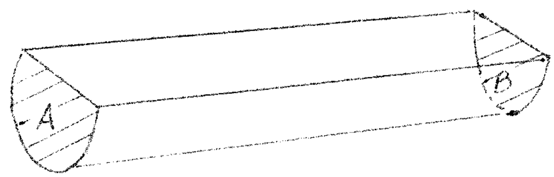
27. When calculating results how are results expressed if all pl: < 20 or > 60 colonies? < > Estimated no.
Results should be identified as estimated.
The exception is when water quality is good and <20 colonies this case the lower limit can be ignored (SM p893, #6a: SSM p78,

28. How are results calculated?
Standard Methods procedure is (SM p893, #6a: SSM p79):

$$\text{Fecal coliforms/100 mL} = \frac{\text{\# of fecal coliform colonies counted}}{\text{sample size (mL)}}$$

Appendix B. Time-of-travel calculations for ponded area below WTP.

Time of Ttavel was calculated as the volume of the ponded segment divided by the flow rate. The ponded stretch was divided into six segments with depth transects measured across the creek at six points. Each transect consisted of 10 to 15 depth measurements at two- to four-foot distances across the creek. The volume of each segment was calculated as the product of the segment length (y) and the mean of the upstream and downstream transect areas [(A+B)/2].



The sum of the volumes for the six stretches for the stretch represents the total volume of the ponded area. Since the area of the furthest upstream transect of the first segment is very small, the mean area of the upstream and downstream transects was estimated as 1/2 the downstream transect area.

Segment Number	y (ft)	x	(A+B)/2 (sq ft)	=	Volume (cu ft)
1	100		32.7		1,635
2	180		56.9		10,242
3	150		75.3		11,295
4	300		81.5		24,450
5	320		99.7		31,904
6	650		97.0		63,050
Total					142,576

The mean flow rate above and below the ponded stretch (RM 53.82 and 53.23) during the survey was 0.27 cfs. The time of travel was calculated as:

Volume of the stretch/ Mean flow rate

142,576 cu ft/ 0.27 cu ft/sec =

6.1 days

Appendix C. Results of dawn/dusk dissolved oxygen survey, August 31, 1988.

Station Name	LH 02			RM 54.3			RM 53.88			RM 53.85			RM 53.82			RM 53.23		
Time	0615	0615	1800	0600	0600	1745	0540	0540	1730	0545	0545	1730	0530	0530	1715	0515	0515	1630
Temperature (^{o}C)	13.4	13.4	16.7	14.2	14.3	20.9	13.3	13.3	17.8	14.1	14.1	20.3	13.7	13.7	20.3	16.1	16.1	19.5
pH (S.U.)	7.35	7.35	7.35	7.59	7.59	8.02	7.98	7.98	8.51	7.59	7.59	8.07	7.39	7.39	7.88	7.37	7.37	7.43
Dissolved Oxygen (mg/L)	2.5	2.7	2.4	5.9	6.2	8.5	7.5	7.3	11.5	5.3	5.3	10.1	1.8	1.9	8.8	2.0	2.1	3.4
Dissolved Oxggen (% sat)	26.1	28.2	26.9	62.8	66.0	103.3	78.1	76.0	131.6	56.2	56.2	121.4	18.9	20.0	105.8	22.1	23.2	40.2

Appendix D. Results of macroinvertebrate analysis for replicate samples at Hangman Creek on August 31, 1988.

Rare (R)=1-5; Few (F)=6-10; Common (C)=11-25; Abundant(A)= >25

		Stations					
Order	Family	53.88(A)	53.88(B)	53.85(A)	53.85(B)	53.23(A)	53.23(B)
Ephemeroptera	Baetidae	C	C	F	F		F
	Caenidae			F		F	
Anisoptera	Aeshnidae	R			R		
	Gomphidae	R			R		
Zygoptera	Coenagrionidae		A	A	A	F	C
Diptera	Chiromnidae			A	A	F	F
	Culicidae	F	F	A	A		
Amphipoda	Talidradae		R	R	R		C
Gastropda	Pysidae	F	C	R	F	R	
	Planorbidae	C	A	A			
	Ancylidae	R				R	
	Lymnaeid		R				
Hemiptera	Gerridae	R	A				
	Balostomatidae		R			R	
Pelecypoda	Sphaeriidae		R				
Decapoda		R	F		R		
Cladocera				R		R	
Copepoda				A	A		
Hirudinea					R		
Oligochaeta						R	
Coleoptera						R	
Hydracarina		A	A	A	F	A	A
Total No. of Taxa		10	12	10	12	9	5

Coefficient of Community Analysis (Courtemanch and Davies, 1987)

$I = (a-b)/b$

where
- I = coefficient of community loss
- a = No. of taxa in the reference (upstram) community (mean of 2 replicates)
- b = No. of taxa in the pollution-affected community (mean of 2 replicates)
- c = No. of taxa common to both reference and pollution-affected community

Comparison of 53.88 (upstream) with 53.23 (0.6 mile downstream):

$I = (10.5-4)/6.5$

$I = 1.08$

Comparison of 53.88 (upstream) with 53.85 (300 ft. downstream):

$I = (11-11)/9$

$I = 0$

Appendix E. Analysis of dissolved oxygen sag below Tekoa WTP using the Streeter-Phelps model (after Mills et al. 1985; see example IV-9 in EPA 600/6-85/002a). (Tables E-1 through E-20)

Table E-1. D.O. model results using conditions found during August 30-31, 1988. (Top # 1-15 = model input; bottom #1-10 = model output).

INPUT **

1. UPSTREAM DISCHARGE (cfs)..................................:	0.09
2. EFFLUENT DISCHARGE (cfs)..................................:	0.15
3. UPSTREAM DO CONCENTRATION (mg/L)..........................:	7.3
4. EFFLUENT DO CONCENTRATION.................................:	6.4
5. UPSTREAM CBOD (Ultimate) CONCENTRATION (mg/L).............:	3
6. EFFLUENT CBOD (Ultimate) CONCENTRATION (mg/L).............:	19
7. UPSTREAM NBOD CONCENTRATION (mg/L)........................:	2.6
8. EFFLUENT NBOD CONCENTRATION (mg/L)........................:	14
9. STREAM VELOCITY (fps).....................................:	0.005
10. STREAM DEPTH (ft)..:	2
11. STREAM SLOPE (ft/ft).....................................:	0.002
12. AVERAGE ELEVATION OF RIVER REACH (FT MSL)................:	2490
13. STREAM TEMPERATURE (deg C)...............................:	20
14. REAERATION RATE (Base e) AT 20 deg C (day^-1)............:	0.4

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Value
Churchill	1.5 - 6	2 - 50	0.02
O'Connor and Dobbins	0.1 - 1.5	2 - 50	0.32
Owens	0.1 - 6	1 - 2	0.17
Tsiviglou-Wallace	0.1 - 6	0.1 - 2	0.08

15. BOD DECAY RATE (Base e) AT 20 deg C (day^-1).............:	0.2

CALCULATED VALUES ***

1. DO SATURATION CONCENTRATION (mg/L)........................:	8.2
2. INITIAL DO CONCENTRATION (mg/L)...........................:	6.7
3. INITIAL DO DEFICIT (mg/L).................................:	1.5
4. INITIAL DOWNSTREAM BOD CONCENTRATION (mg/L)................	22.73
5. REARATION RATE AT STREAM TEMPERATURE (day^-1).............:	0.40
6. BOD DECAY RATE AT STREAM TEMPERATURE (day^-1).............:	0.20
7. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days)...........:	3.13
8. DISTANCE TO CRITICAL DO CONCENTRATION (miles).............:	0.26
9. CRITICAL DO DEFICIT (mg/L)................................:	6.1
10. CRITICAL DO CONCENTRATION (mg/L).........................:	2.1

****

Table E-2. D.O. model results under design conditions: 0.2 MGD and estimated 7Q10 flow (Top # 1-15 = model input; bottom #1-10 = model output).

INPUT ***

1.	UPSTREAM DISCHARGE (cfs)....................................:	0.15
2.	EFFLUENT DISCHARGE (cfs)....................................:	0.3
3.	UPSTREAM DO CONCENTRATION (mg/L)............................:	7.3
4.	EFFLUENT DO CONCENTRATION...................................:	6.4
5.	UPSTREAM CBOD (Ultimate) CONCENTRATION (mg/L)...............:	3
6.	EFFLUENT CBOD (Ultimate) CONCENTRATION (mg/L)...............:	44
7.	UPSTREAM NBOD CONCENTRATION (mg/L)..........................:	2.6
8.	EFFLUENT NBOD CONCENTRATION (mg/L)..........................:	14
9.	STREAM VELOCITY (fps).......................................:	0.005
10.	STREAM DEPTH (ft)...:	2
11.	STREAM SLOPE (ft/ft)..:	0.002
12.	AVERAGE ELEVATION OF RIVER REACH (FT MSL)...................:	2490
13.	STREAM TEMPERATURE (deg C)..................................:	20
14.	REAERATION RATE (Base e) AT 20 deg C (day^-1)...............:	0.4

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Value
Churchill	1.5 - 6	2 - 50	0.02
O'Connor and Dobbins	0.1 - 1.5	2 - 50	0.32
Owens	0.1 - 6	1 - 2	0.17
Tsiviglou-Wallace	0.1 - 6	0.1 - 2	0.08

15.	BOD DECAY RATE (Base e) AT 20 deg C (day^-1)................:	0.2

CALCULATED VALUES ***

1.	DO SATURATION CONCENTRATION (mg/L)..........................:	8.2
2.	INITIAL DO CONCENTRATION (mg/L).............................:	6.7
3.	INITIAL DO DEFICIT (mg/L)...................................:	1.5
4.	INITIAL DOWNSTREAM BOD CONCENTRATION (mg/L).................	40.53
5.	REARATION RATE AT STREAM TEMPERATURE (day^-1)...............:	0.40
6.	BOD DECAY RATE AT STREAM TEMPERATURE (day^-1)...............:	0.20
7.	TRAVEL TIME TO CRITICAL DO CONCENTRATION (days).............:	3.27
8.	DISTANCE TO CRITICAL DO CONCENTRATION (miles)...............:	0.27
9.	CRITICAL DO DEFICIT (mg/L)..................................:	10.5
10.	CRITICAL DO CONCENTRATION (mg/L)............................:	0.0

****

Table E-3. D.O. model results assuming 1.0 cfs upstream of the Tekoa discharge and design capacity, 0.2 MGD (Top # 1-15 = model input; bottom #1-10 = model output).

INPUT **

1. UPSTREAM DISCHARGE (cfs).....................................:	1.0
2. EFFLUENT DISCHARGE (cfs).....................................:	0.3
3. UPSTREAM DO CONCENTRATION (mg/L).............................:	7.3
4. EFFLUENT DO CONCENTRATION....................................:	6.4
5. UPSTREAM CBOD (Ultimate) CONCENTRATION (mg/L)................:	3
6. EFFLUENT CBOD (Ultimate) CONCENTRATION (mg/L)................:	44
7. UPSTREAM NBOD CONCENTRATION (mg/L)...........................:	2.6
8. EFFLUENT NBOD CONCENTRATION (mg/L)...........................:	14
9. STREAM VELOCITY (fps)..:	0.05
10. STREAM DEPTH (ft)...:	2.3
11. STREAM SLOPE (ft/ft)..:	0.002
12. AVERAGE ELEVATION OF RIVER REACH (FT MSL)....................:	2490
13. STREAM TEMPERATURE (deg C)..................................:	20
14. REAERATION RATE (Base e) AT 20 deg C (day^-1)...............:	1.0

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Value
Churchill	1.5 - 6	2 - 50	0.16
O'Connor and Dobbins	0.1 - 1.5	2 - 50	0.83
Owens	0.1 - 6	1 - 2	0.62
Tsiviglou-Wallace	0.1 - 6	0.1 - 2	0.78

15. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)................:	0.2

CALCULATED VALUES ***

1. DO SATURATION CONCENTRATION (mg/L)...........................:	8.2
2. INITIAL DO CONCENTRATION (mg/L)..............................:	7.1
3. INITIAL DO DEFICIT (mg/L)....................................:	1.1
4. INITIAL DOWNSTREAM BOD CONCENTRATION (mg/L).................	17.69
5. REARATION RATE AT STREAM TEMPERATURE (day^-1)................:	1.00
6. BOD DECAY RATE AT STREAM TEMPERATURE (day^-1)................:	0.20
7. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days)..............:	1.64
8. DISTANCE TO CRITICAL DO CONCENTRATION (miles)................:	1.34
9. CRITICAL DO DEFICIT (mg/L)...................................:	2.5
10. CRITICAL DO CONCENTRATION (mg/L)............................:	5.7

****

Table E-4. D.O. model results assuming 1.8 cfs upstream of the Tekoa discharge and design capacity, 0.2 MGD (Top # 1-15 = model input; bottom #1-10 = model output).

INPUT **

1. UPSTREAM DISCHARGE (cfs)....................................: 1.8
2. EFFLUENT DISCHARGE (cfs)....................................: 0.3
3. UPSTREAM DO CONCENTRATION (mg/L)...........................: 7.3
4. EFFLUENT DO CONCENTRATION...................................: 6.4
5. UPSTREAM CBOD (Ultimate) CONCENTRATION (mg/L)..............: 3
6. EFFLUENT CBOD (Ultimate) CONCENTRATION (mg/L)..............: 44
7. UPSTREAM NBOD CONCENTRATION (mg/L).........................: 2.6
8. EFFLUENT NBOD CONCENTRATION (mg/L).........................: 14
9. STREAM VELOCITY (fps)......................................: 0.05
10. STREAM DEPTH (ft)...: 2.3
11. STREAM SLOPE (ft/ft)......................................: 0.002
12. AVERAGE ELEVATION OF RIVER REACH (FT MSL).................: 2490
13. STREAM TEMPERATURE (deg C)................................: 20
14. REAERATION RATE (Base e) AT 20 deg C (day^-1).............: 1.5

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Value
Churchill	1.5 - 6	2 - 50	0.16
O'Connor and Dobbins	0.1 - 1.5	2 - 50	0.83
Owens	0.1 - 6	1 - 2	0.62
Tsiviglou-Wallace	0.1 - 6	0.1 - 2	0.78

15. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)..............: 0.2

CALCULATED VALUES **

1. DO SATURATION CONCENTRATION (mg/L).........................: 8.2
2. INITIAL DO CONCENTRATION (mg/L)............................: 7.2
3. INITIAL DO DEFICIT (mg/L)..................................: 1.1
4. INITIAL DOWNSTREAM BOD CONCENTRATION (mg/L)................. 13.09
5. REARATION RATE AT STREAM TEMPERATURE (day^-1)..............: 1.50
6. BOD DECAY RATE AT STREAM TEMPERATURE (day^-1)..............: 0.20
7. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days)............: 0.98
8. DISTANCE TO CRITICAL DO CONCENTRATION (miles)..............: 0.80
9. CRITICAL DO DEFICIT (mg/L).................................: 1.4
10. CRITICAL DO CONCENTRATION (mg/L)..........................: 6.8

****

Table E-5. D.O. model results assuming 2.0 cfs upstream of the Tekoa discharge and design capacity, 0.2 MGD (Top # 1-15 = model input; bottom #1-10 = model output).

INPUT **

1. UPSTREAM DISCHARGE (cfs)....................................:	2.0
2. EFFLUENT DISCHARGE (cfs)....................................:	0.3
3. UPSTREAM DO CONCENTRATION (mg/L)............................:	7.3
4. EFFLUENT DO CONCENTRATION...................................:	6.4
5. UPSTREAM CBOD (Ultimate) CONCENTRATION (mg/L)...............:	3
6. EFFLUENT CBOD (Ultimate) CONCENTRATION (mg/L)...............:	19
7. UPSTREAM NBOD CONCENTRATION (mg/L)..........................:	2.6
8. EFFLUENT NBOD CONCENTRATION (mg/L)..........................:	14
9. STREAM VELOCITY (fps).......................................:	0.11
10. STREAM DEPTH (ft)..:	2.5
11. STREAM SLOPE (ft/ft).......................................:	0.002
12. AVERAGE ELEVATION OF RIVER REACH (FT MSL)..................:	2490
13. STREAM TEMPERATURE (deg C).................................:	20
14. REAERATION RATE (Base e) AT 20 deg C (day^-1)..............:	2.2

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Value
Churchill	1.5 - 6	2 - 50	0.29
O'Connor and Dobbins	0.1 - 1.5	2 - 50	1.09
Owens	0.1 - 6	1 - 2	0.90
Tsiviglou-Wallace	0.1 - 6	0.1 - 2	1.71

15. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)...............:	0.2

CALCULATED VALUES **

1. DO SATURATION CONCENTRATION (mg/L)..........................:	8.2
2. INITIAL DO CONCENTRATION (mg/L).............................:	7.2
3. INITIAL DO DEFICIT (mg/L)...................................:	1.0
4. INITIAL DOWNSTREAM BOD CONCENTRATION (mg/L).................	9.17
5. REARATION RATE AT STREAM TEMPERATURE (day^-1)...............:	2.20
6. BOD DECAY RATE AT STREAM TEMPERATURE (day^-1)...............:	0.20
7. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days).............:	0.00
8. DISTANCE TO CRITICAL DO CONCENTRATION (miles)...............:	0.00
9. CRITICAL DO DEFICIT (mg/L)..................................:	1.0
10. CRITICAL DO CONCENTRATION (mg/L)...........................:	7.2

****

Table E-6. D.O. model results assuming 3.0 cfs upstream of the Tekoa discharge and design capacity, 0.2 MGD (Top # 1-15 = model input; bottom #1-10 = model output).

INPUT **

1. UPSTREAM DISCHARGE (cfs)....................................:	3.0
2. EFFLUENT DISCHARGE (cfs)....................................:	0.3
3. UPSTREAM DO CONCENTRATION (mg/L)............................:	7.3
4. EFFLUENT DO CONCENTRATION...................................:	6.4
5. UPSTREAM CBOD (Ultimate) CONCENTRATION (mg/L)..............:	3
6. EFFLUENT CBOD (Ultimate) CONCENTRATION (mg/L)..............:	19
7. UPSTREAM NBOD CONCENTRATION (mg/L)..........................:	2.6
8. EFFLUENT NBOD CONCENTRATION (mg/L)..........................:	14
9. STREAM VELOCITY (fps).......................................:	0.17
10. STREAM DEPTH (ft)..:	2.5
11. STREAM SLOPE (ft/ft).......................................:	0.002
12. AVERAGE ELEVATION OF RIVER REACH (FT MSL).................:	2490
13. STREAM TEMPERATURE (deg C).................................:	20
14. REAERATION RATE (Base e) AT 20 deg C (day^-1).............:	2.80

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Value
Churchill	1.5 - 6	2 - 50	0.45
O'Connor and Dobbins	0.1 - 1.5	2 - 50	1.35
Owens	0.1 - 6	1 - 2	1.21
Tsiviglou-Wallace	0.1 - 6	0.1 - 2	2.64

15. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)..............:	0.2

CALCULATED VALUES **

1. DO SATURATION CONCENTRATION (mg/L)..........................:	8.2
2. INITIAL DO CONCENTRATION (mg/L).............................:	7.2
3. INITIAL DO DEFICIT (mg/L)...................................:	1.0
4. INITIAL DOWNSTREAM BOD CONCENTRATION (mg/L).................	8.09
5. REARATION RATE AT STREAM TEMPERATURE (day^-1)..............:	2.80
6. BOD DECAY RATE AT STREAM TEMPERATURE (day^-1)..............:	0.20
7. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days)............:	0.00
8. DISTANCE TO CRITICAL DO CONCENTRATION (miles)..............:	0.00
9. CRITICAL DO DEFICIT (mg/L)..................................:	1.0
10. CRITICAL DO CONCENTRATION (mg/L)..........................:	7.2

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Table E-7. D.O. model results assuming 4.0 cfs upstream of the Tekoa discharge and design capacity, 0.2 MGD (Top # 1-15 = model input; bottom #1-10 = model output).

INPUT **

1. UPSTREAM DISCHARGE (cfs)....................................:	4.0
2. EFFLUENT DISCHARGE (cfs)....................................:	0.3
3. UPSTREAM DO CONCENTRATION (mg/L)............................:	7.3
4. EFFLUENT DO CONCENTRATION...................................:	6.4
5. UPSTREAM CBOD (Ultimate) CONCENTRATION (mg/L)..............:	3
6. EFFLUENT CBOD (Ultimate) CONCENTRATION (mg/L)..............:	19
7. UPSTREAM NBOD CONCENTRATION (mg/L)..........................:	2.6
8. EFFLUENT NBOD CONCENTRATION (mg/L)..........................:	14
9. STREAM VELOCITY (fps).......................................:	0.22
10. STREAM DEPTH (ft)..:	2.8
11. STREAM SLOPE (ft/ft).......................................:	0.002
12. AVERAGE ELEVATION OF RIVER REACH (FT MSL)..................:	2490
13. STREAM TEMPERATURE (deg C).................................:	20
14. REAERATION RATE (Base e) AT 20 deg C (day^-1)..............:	3.50

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggested Value
Churchill	1.5 - 6	2 - 50	0.48
O'Connor and Dobbins	0.1 - 1.5	2 - 50	1.30
Owens	0.1 - 6	1 - 2	1.17
Tsiviglou-Wallace	0.1 - 6	0.1 - 2	3.42

15. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)...............:	0.2

CALCULATED VALUES **

1. DO SATURATION CONCENTRATION (mg/L)..........................:	8.2
2. INITIAL DO CONCENTRATION (mg/L).............................:	7.2
3. INITIAL DO DEFICIT (mg/L)...................................:	1.0
4. INITIAL DOWNSTREAM BOD CONCENTRATION (mg/L).................	7.51
5. REARATION RATE AT STREAM TEMPERATURE (day^-1)...............:	3.50
6. BOD DECAY RATE AT STREAM TEMPERATURE (day^-1)...............:	0.20
7. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days).............:	0.00
8. DISTANCE TO CRITICAL DO CONCENTRATION (miles)...............:	0.00
9. CRITICAL DO DEFICIT (mg/L)..................................:	1.0
10. CRITICAL DO CONCENTRATION (mg/L)...........................:	7.2

****